AD-A063 736 OKLAHOMA STATE UNIV STILLWATER DEPT OF STATISTICS F/G 12/1
A STATISTICAL TOOL: ANALYSIS OF COVARIANCE. VOLUME III. PROGRAM--ETC(U)
APR 77 S CAUDILL, D HOLBERT, L D BROEMELING F08635-76-C-0154

UNCLASSIFIED AFATL-TR-77-54-VOL-3 NL

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A STATISTICAL TOOL: ANALYSIS OF COVARIANCE

VOLUME III: PROGRAM LISTING, FLOW CHART AND USER'S MANUAL FOR ALGORITHM FOR HANDLING MULTIVARIATE COVARIANCE DATA WITH MISSING VALUES

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APRIL 1977

FINAL REPORT FOR PERIOD
JANUARY 1976-DECEMBER 1976

AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
EGLIN AIR FORCE BASE, FLORIDA

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 18 AFATL-TR-77-54, VOLUME III

2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER: 19 TR-77-54-VOL-3

4. TITLE (and Subtitle): 6 A STATISTICAL TOOL: ANALYSIS OF COVARIANCE. VOLUME III. PROGRAM LISTING, FLOW CHART, AND USER'S MANUAL FOR ALGORITHM FOR HANDLING MULTIVARIATE COVARIANCE DATA WITH MISSING VALUES.

5. TYPE OF REPORT & PERIOD COVERED: 9 Final Report. January - December 1976,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): 10 Sam Caudill, Dr. Don Holbert, Dr. Lyle D. Broemeling

8. CONTRACT OR GRANT NUMBER(s): 15 F08635-76-C-0154

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Department of Statistics
Oklahoma State University
Stillwater, Oklahoma 74074

411038

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
Program Element 62602F
JON 16 2549-04-07 17 04

11. CONTROLLING OFFICE NAME AND ADDRESS:
Air Force Armament Laboratory
Armament Development and Test Center
Eglin Air Force Base, Florida 32542

12. REPORT DATE: 11 April 1977

13. NUMBER OF PAGES: 90

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 92 p.

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available in DDC

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Analysis of Covariance
Covariance Analysis
Missing Data Routings

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews the theoretical framework which permits analysis of multivariate covariance data in which missing values occur among both dependent and independent variables.

A flow chart and program listing is given for a computer program which will estimate the block and treatment parameters, as well as the regression coefficients for the covariates. The program will also calculate test statistics for testing hypotheses which are supplied by the user. -> next page

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cont.

It should be pointed out that this program allows for only two categories of design indicator variables, namely a block effect and a treatment effect which are assumed to be additive. The program is thus suitable for the usual randomized block model with additive block and treatment effects, or a general two-factor additive effects model (i.e., no interaction), or the usual one-way classification model (i.e., several treatments but only one block). It will not accommodate more complex designs such as a Latin Square Layout with a multivariate response and one or more covariates.

User instructions and a worked example are provided in this volume.

PREFACE

This report consists of three volumes which present the theory and application of a valuable data reduction tool, the analysis of covariance. Volume I introduces the analysis of covariance as a general linear model (GLM) and then expands the model to incorporate the multivariate case, unequal sample size, and missing observations on the response variable. Volume I also covers the analysis of covariance for nonparametric data.

Volumes II and III were prepared by the Department of Statistics, Oklahoma State University, Stillwater, Oklahoma 74074, under Air Force Contract F08635-76-C-0154, with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida 32542. The contract dealt with the development and programming of the methodology for evaluating multiple variable data with missing observations on dependent and independent variables by the analysis of covariance method. The methodology also covers case for unequal sample size. This work was begun in January 1976 and completed in December 1976. This is Volume III.

This report has been reviewed by the information Officer (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

J R Murray

J. R. MURRAY
Chief, Analysis Division

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TABLE OF CONTENTS

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SECTION I

INTRODUCTION

Many techniques in multivariate analysis, such as multiple regression, principal component analysis, and canonical correlation, assume that one has an array of numbers $(Y_{i_1}, Y_{i_2}, \cdots, Y_{i_p}, X_{i_1}, X_{i_2}, \cdots, X_{i_q})$, $i = 1, \cdots, n$ on which various operations are performed. In ordinary multiple linear regression with a single dependent variable, p will be 1; in a designed experiment, some of the X's will be treatment and block indicators taking only the values 0 or 1.

In various experimental environments, it is not uncommon that some of the Y values and/or X values will be missing, resulting in one or more incomplete observations: an animal dies, a test tube breaks, a piece of equipment malfunctions, or a measuring instrument fails to record as intended.

Most computer programs currently available require that complete observations only be supplied for analysis. One therefore has the choice of discarding any observations on which at least one of the variables is missing, or using an estimation technique of some kind to fill in the missing values before submitting the data for computer analysis. If missing values occur frequently, the first alternative can result in a drastic reduction in the amount of data available for analysis. The second alternative presents difficult problems in estimation; no technique is available which works well under all circumstances. (See, for example, Haitovsky (1968).)

In Section II the results of a technique developed to handle the situation are discussed. Missing values occur among either dependent or independent variables, but not in the block or treatment design indicator variables. Full details of the theoretical development, an

extension of the work of Kleinbaum (1973), are given in Volume I. The proposed approach requires neither the discarding of incomplete observations nor the prior estimation of missing values.

In Section III, user instructions are provided for a computer program written to perform an analysis of a set of data by the methods given in Section II. Section IV provides a worked example, while a flow chart and program listing are given in Appendices A and B, respectively.

SECTION II

REVIEW OF THE THEORETICAL FRAMEWORK

The theory, for a multivariate analysis of covariance model in which missing observations occur among the dependent and/or independent variables, was developed in Volume I, resulting in a general procedure which yields Best Asymptotic Normal (BAN) estimators of the design parameters and regression slopes and which allows hypothesis tests based on statistics which are asymptotically distributed as chi-square variables. Equation 10, described in Section III of Volume I, is used for the computation of a consistent and unbiased estimate of the variance-covariance matrix Σ. The value of $\hat{\Sigma}$ thus obtained is then used to obtain estimates of the design parameters, regression slopes, and chi-square statistics for the hypothesis tests. Although the formulae used to obtain these BAN estimates and test statistics are different in form from those described in Volume I, they are mathematically equivalent and are used in the actual calculations only to make the computations manageable on an electronic computer. These alternative formulae are obtained from the Matrix Modified representation of the MGMAC model which is described in the following paragraphs.

To obtain the general form of the Matrix Modified representation of the MGMAC model, assume that there are n experimental units and p response variates $V_1, \cdots, V_p$ in total and that the model can be written in the form

$$E(Y) = X\alpha + Z\beta$$

$$\text{Var}(Y) = I_n \otimes \Sigma$$

where Y is an nxp matrix composed of p-variate responses on n individuals with missing values recorded as blanks,

X is an $n \times m_x$ known design matrix of rank $R(x) = r_x (\leq m_x \leq n)$ corresponding to the classificatory variables of the model,

α is an $m_x xp$ matrix of unknown parameters

Z is an nxm_z matrix composed of concomitant variables with missing values recorded as blanks,

β is an $m_z xp$ matrix of unknown concomitant parameters.

$\Sigma = ((\sigma_{rs}))$ is a pxp positive definite matrix of usually unknown parameters which represents the variance-covariance matrix of any row of Y, and $A \otimes B$ is the Kronecker Product of the matrices A and B.

Then replace Z by Z* where Z* is derived from Z by augmenting Z (with 0's in place of missing values) by a matrix G of dimension (nxt) composed of t columns each with a one in the row position corresponding to the missing values in Z and zeroes elsewhere. (Note: Z has dimension (nxm_z^*) where $m_z^* = m_z + t$). Thus, the Matrix Modified representation of the MGMAC model may be written in the form

$$E(Y) = X\alpha + Z^*\binom{\beta}{\delta} \qquad (1)$$

$$\mathrm{Var}(Y) = In \otimes \Sigma$$

where δ is a (txp) matrix of unknown parameters due to the t missing values in Z. Missing values in Y are then handled by an approach suggested by Srivastava (3) for incomplete multiresponse designs and later by Kleinbaum (1) for the MGLM model. For simplification of notation, the model [Equation (1)] is first written in the form

$$E(Y) = A^* \xi$$

$$\mathrm{Var}(Y) = In \otimes \Sigma$$

where $A^*(nxm^*) = [X \mid Z^*]$, $m^* = m_x + m_z^*$ and $\xi(m^*xp) = \begin{bmatrix} \alpha \\ \beta \\ \delta \end{bmatrix}$. The n experimental units are then divided into u disjoint sets of experimental units $S_1, S_2, \ldots, S_u$ with n_j units in S_j. On each unit in the set S_j only $q_j (\le p)$ responses are observed (i.e.,the remaining $p-q_j$ response variates are missing in S_j). Therefore, the MGMAC model is given by

$E(Y_j) = A_j^* \xi B_j$

$Var(Y_j) = In \otimes B_j' \Sigma B_j$, $j = 1,2,\ldots,u$

where $Y_j(n_j \times q_j)$ is the matrix of observations for the jth set S_j

$A_j^*(n_j \times m^*)$ is the design matrix for the set S_j,

$B_j(p \times q_j)$ is the incidence matrix of rank $R(B_j) = q_j$ for the jth set of experimental units. It consists of 0's and 1's and is defined by $B_j = ((b_{(j)_{se}}))$ where

$$b_{(j)_{sr}} = \begin{cases} 1 \text{ if variate } V_s \text{ is the } r\text{th ordered variate} \\ \quad \text{measured in the } j\text{th experimental set } S_j \\ 0 \text{ otherwise.} \end{cases}$$

It is also assumed that Y_j and Y_j' are independent if $j \neq j'$ and the rows of Y_j are independent and distributed as a q_j-variate multinormal vector with variance-covariance matrix $B_j' \Sigma B_j$.

Based on the above Matrix Modified representation of the MGMAC model, the following results for estimation and hypothesis testing are obtained.

Theorem 1. A BAN estimator for an estimable linear set $\underline{\Theta} = H'\underline{\xi}$ is given by

$$\hat{\underline{\Theta}}_n = H'\hat{\underline{\xi}} = H'[\sum_{j=1}^{u} B_j(B_j' \hat{\Sigma} B_j)^{-1}B_j' \otimes A_j^{*\prime}A^*]^{-} \sum_{j=1}^{u} [B_j(B_j'\hat{\Sigma}B_j)^{-1} \otimes A_j^{*\prime}] \underline{y}_j$$

where $\hat{\Sigma}$ is defined in Theorem 4 of Volume I and $\underline{y}_j$ is formed by stacking the columns of Y_j underneath each other.

Theorem 2. The Wald Statistic for testing the hypothesis H_o: $H'\underline{\xi} = 0$ is given by

$$W_n = (H'\hat{\underline{\xi}})' \{H'[\sum_{j=1}^{u} B_j(B_j'\hat{\Sigma}B_j)^{-1}B_j' \otimes A_j^{*\prime}A_j]^{-} H\}^{-1} H'\hat{\underline{\xi}} .$$

Note: The above theorems follow easily from similar theorems by Kleinbaum (1).

SECTION III

INSTRUCTIONS FOR USE OF THE COMPUTER PROGRAM

In this section are outlined the steps for preparation of data cards and control cards necessary for execution of the computer program. A worked example illustrating these ideas and the resulting computer output is presented in the next section.

PREPARATION OF DATA CARDS

The methodology and computer program presented in this report were designed to assist in analyzing data from an experiment in which a complete observation consists of a block identifier, a treatment identifier, numerical values on one or more concomitant variables (covariables, independent variables), and numerical values on one or more dependent variables (response variables). For example, a complete observation may come from a single shot down a firing range, where block corresponds to metal type, treatment corresponds to projectile shape, the covariables are such things as initial projectile weight and initial projectile velocity, and the dependent variables are residual projectile weight, residual projectile velocity, and plug weight.

For this program the data card(s) corresponding to a complete observation should contain a block number, a treatment number, the covariables, and the dependent variables, as well as any identification the user desires. The order in which these occur on the card is not important. It is necessary, however, that both blocks and treatments be numbered sequentially beginning with "1."

The data card corresponding to the observation on block 3, treatment 2, may look like:

$$\underbrace{\text{TEST 06 SITE A}}_{\text{Identification}} \quad \underbrace{3 \qquad 2}_{\text{Blk \& Trt}} \quad \underbrace{113.8 \quad 680}_{\text{X's}} \quad \underbrace{110.7 \quad 507 \quad 8.9}_{\text{Y's}}$$

MISSING VALUES

The user is free to choose any number he desires to correspond to missing values among the Y's or X's. This number will then be punched in the data card for any X or Y value which, for reasons reviewed in Section I, was not recorded when the experiment was conducted. Of course, the selected number must not be the same as any of the X or Y values occurring in the data set being analyzed and must also be of a magnitude which allows it to be coded in the number of columns provided for the X's and Y's. Suppose that, in the example above, both 113.8 and 507 had not been recorded and were to be treated as missing values. If the missing value code selected by the user was 44.4, the card would have been punched as:

```
TEST 06 SITE A   3   2   044.4  680   110.7  44.4   8.9
```

CONTROL CARDS

We now present in sequence a description of the control cards which must accompany every job.

Control Card 1 - Current Data Set Information

The first 21 columns of this card consist of seven three-digit (i.e., I3) fields which contain in order the values of

NP	The number of dependent variables (Y's)	NP $\geq$ 1
NT	The number of treatments	NT $\geq$ 1
NB	The number of blocks	NB $\geq$ 1
NK	The number of covariates (X's)	NK $\geq$ 1
NN	The number of observations	
IDGT	An input parameter to the LPSDOR subroutine (which computes a generalized inverse of a matrix). The elements of the matrix are assumed to be correct to IDGT places. Since this program computes the matrix elements in double precision, we suggest that the user supply IDGT=14.	

NMISS - The number of missing values in the covariates only. Do not include, in this count, missing values in the dependent variables.

The next 8 columns are blank. Beginning in column 30 punch

Columns 30-39: EPS - A test value for zero which is used in the DMFGR subroutine which calculates the rank of a matrix. Suggest user let EPS = 1.0E - 07.

Columns 40-49: D - The double precision missing value code described in an earlier subsection of this section. In that subsection we used, as an example, a missing value code of 44.4. In this case we would code D = 44.4 DO.

Columns 50-63: These columns contain seven two-digit (I2) fields indicating the desired print options for the analysis. Each I2 field contains either "00," which requests that the printing be suppressed, or "01," which requests that the printing not be suppressed. In order, the 7 codes refer to

Columns 50-51: Print option for listing of MAC model.

Columns 52-53: Print option for listing of GMAC model.

Columns 54-55: Print option for listing of MGMAC model.

Columns 56-57: Print option for listing of sigma and its inverse.

Columns 58-59: Print option for listing of the matrix modified model.

Columns 60-61: Print option for subgroups of observations corresponding to the different patterns of missing values.

Columns 62-63: Print option for beta values.

With regard to the user's choice of the print options, we suggest that, for most purposes, it would be sufficient to code columns 50 through 63 with "01000001000001." This provides the user with a listing of the MAC model, sigma and its inverse, and the beta values as well as results of hypothesis tests.

Control Card 2 - Variable Format for the Input Data Set

On this card the user supplies a FORTRAN format statement which specifies the columns in which the block number, treatment number, dependent

variables (Y_i, i = 1, ···, NP), and covariables (X_j, j = 1, ···, NK), in that order, are to be found. The block and treatment numbers must be read according to an Iw format, while the dependent and independent variables would ordinarily be read with F w.d or D w.d formats. This card must begin with a left parenthsis (in column 1) and end with a right parenthesis and contain no intervening blanks. For our example in the first subsection of this section, the variable format card would be

(T18, I1,6X,I1,T42,F5.1,1X,F4.0,3X,F4.1,T30,F5.1,1X,F4.0).

Control Card 3 - Number of Hypothesis Matrices Being Supplied

This is the simplest of all the control cards and merely states how many hypothesis matrices are to be supplied to provide basis for hypothesis tests for the particular job. This is an integer, NUMHYP, which is punched, right justified, in the first 5 columns of the card. Ordinarily this number will be less than 10, so that only column 5 need be punched.

Remaining Control Cards

Next, we must supply one group of cards for each of the hypotheses to be tested. The first card provides the following information relative to each hypothesis:

Columns 1-5:	The number of rows, NR, in the hypothesis matrix. This is an integer, right justified in columns 1-5.
Columns 6-25:	Any alphameric code which identifies the hypothesis being tested. This is simply an identification which will be listed with the output in the hypothesis testing section of the printout.
Columns 26-27:	"00" if the user does not desire to have the test statistic evaluated for this hypothesis on all NP response variables simultaneously. "01" if the user does desire to have the test statistic evaluated for this hypothesis on all NP response variables simultaneously.
Columns 28-29:	"00" if the user does not desire to have the test statistic evaluated for this hypothesis on the first response variable separately. "01" if the user desires to have the test statistic evaluated for this hypothesis on the first response variable separately.

.   .
.   .
.   .

Columns ((26+ 2NP)-(27+2NP)):	"00" is the user does not desire to have the test statistic evaluated for this hypothesis on the NP^{th} response variable separately. "01" if the user does desire to have the test statistic evaluated for this hypothesis on the NP^{th} response variable separately.

The remaining NR cards in the group for a particular hypothesis give the coefficients for each row of the hypothesis matrix, one row on each of NR cards. These coefficients are read from consecutive four-digit fields according to an F4.2 format. The number of coefficients read per card will be equal to (NB+NT+NK), with the exception that if the data set is composed of one block only (or one treatment only) the number will be (NB+NT+NK-1). This number will, of course, vary from one problem to the next. The number of rows in the hypothesis matrix, NR, will also vary from one hypothesis to the next and from problem to problem.

If we denote by NR_i, $i = 1, \cdots$, NUMHYP, the number of rows in the i^{th} hypothesis being tested, then the number of control cards after control card 3 will be $\sum_{i=1}^{NUMHYP} (NR_i + 1)$.

The method of constructing the hypothesis matrices will be demonstrated in the next subsection.

EXAMPLES ILLUSTRATING CONSTRUCTION OF HYPOTHESIS MATRICES

In Section II, we outlined the general formulation of the assumed model with

$$E(Y) = X\alpha + Z\beta$$

as the underlying mean structure for the data. Here α was an m_x by p matrix of unknown design parameters, and β was an m_z by p matrix of unknown regression coefficients for the concomitant variables. Let us stack the α matrix on the β matrix to form a matrix B. In keeping with the notation used in relation to our computer control cards, this will be a matrix with row dimension (NB+NT+NK) and column dimension NP.

Denoting the block parameters by b_{ij}'s, the treatment parameters by t_{ij}'s, and the regression coefficients by β_{ij}'s, we could think of the B matrix as

$$B = \left[\begin{array}{cccc} b_{11} & b_{12} & \cdots & b_{1_{NP}} \\ \vdots & \vdots & & \vdots \\ b_{NB_1} & b_{NB_2} & \cdots & b_{NB_{NP}} \\ \hline t_{11} & t_{12} & \cdots & t_{1_{NP}} \\ \vdots & \vdots & & \vdots \\ t_{NT_1} & t_{NT_2} & \cdots & t_{NT_{NP}} \\ \hline \beta_{11} & \beta_{12} & \cdots & \beta_{1_{NP}} \\ \vdots & \vdots & & \vdots \\ \beta_{NK_1} & \beta_{NK_2} & \cdots & \beta_{NK_{NP}} \end{array}\right] \begin{array}{l} \left.\vphantom{\begin{array}{c} b \\ \vdots \\ b \end{array}}\right\} \text{NB rows for block parameters} \\ \left.\vphantom{\begin{array}{c} t \\ \vdots \\ t \end{array}}\right\} \text{NT rows for treatment paramters} \\ \left.\vphantom{\begin{array}{c} \beta \\ \vdots \\ \beta \end{array}}\right\} \text{NK rows for regression coefficients} \end{array}$$

This makes it easy to construct full rank hypothesis matrices to test hypotheses of the form H_0: $HB = 0_M$, where H is a full rank hypothesis matrix of dimension r(= rank of H) by (NB + NT + NK) and 0_M is the r by NP matrix containing all zeroes. For example, the hypothesis of no treatment differences (i.e., $t_{1_j} = t_{2_j} = \ldots = t_{NT_j}$ for all j = 1,2,...,NP) can be tested with an H matrix containing (NT-1) orthogonal rows. Similarly, the hypothesis of no influence of covariates ($\beta_{ij} = 0$, i = 1,...,NK; j = 1,...,NP) can be tested with a full rank hypothesis matrix of row dimension NK. Some specific examples will now be given to illustrate the construction of H matrices.

Example 1:

Suppose we have two blocks, two treatments, one covariate, and three response variables. Here NB = NT = 2, NK = 1, and NP = 3. Thus, B can be written

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ \beta_{11} & \beta_{12} & \beta_{13} \end{bmatrix}$$

To test the hypothesis of no treatment differences, H will be the 1 by 5 matrix

$$H = [0 \quad 0 \quad 1 \quad -1 \quad 0].$$

Note that HB = 0 is equivalent to

$$[(t_{11} - t_{21})\ (t_{12} - t_{22})\ (t_{13} - t_{23})] = [0\ 0\ 0].$$

To test the hypothesis of no influence of the covariate, H will be the 1 by 5 matrix

$$H = [0\ 0\ 0\ 0\ 1].$$

Note that HB = 0 is equivalent to

$$[\beta_{11}\quad \beta_{12}\quad \beta_{13}] = [0\quad 0\quad 0].$$

Example 2:

Suppose we have two blocks, four treatments, two covariates, and three response variables. Here NB = 2, NT = 4, NK = 2, and NP = 3. Thus, B can be written

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \\ t_{41} & t_{42} & t_{43} \\ \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \end{bmatrix}$$

To test the hypothesis of no overall treatment differences, H will be the 3 by 8 matrix

$$H = \begin{bmatrix} 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & -2 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & -3 & 0 & 0 \end{bmatrix}.$$

To test the hypothesis of no overall block differences, H will be the 1 by 8 matrix

$$H = [1\ \ -1\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0].$$

To test the hypothesis of no overall effect due to the covariates, H will be the 2 by 8 matrix

$$H = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

To test the hypothesis of no effect due to the first covariate only H will be the 1 by 8 matrix

$$H = [0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0].$$

To test the hypothesis of no difference between treatments one, three and four, H will be the 2 by 8 matrix

$$H = \begin{bmatrix} 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & -2 & 0 & 0 \end{bmatrix}.$$

Example 3.

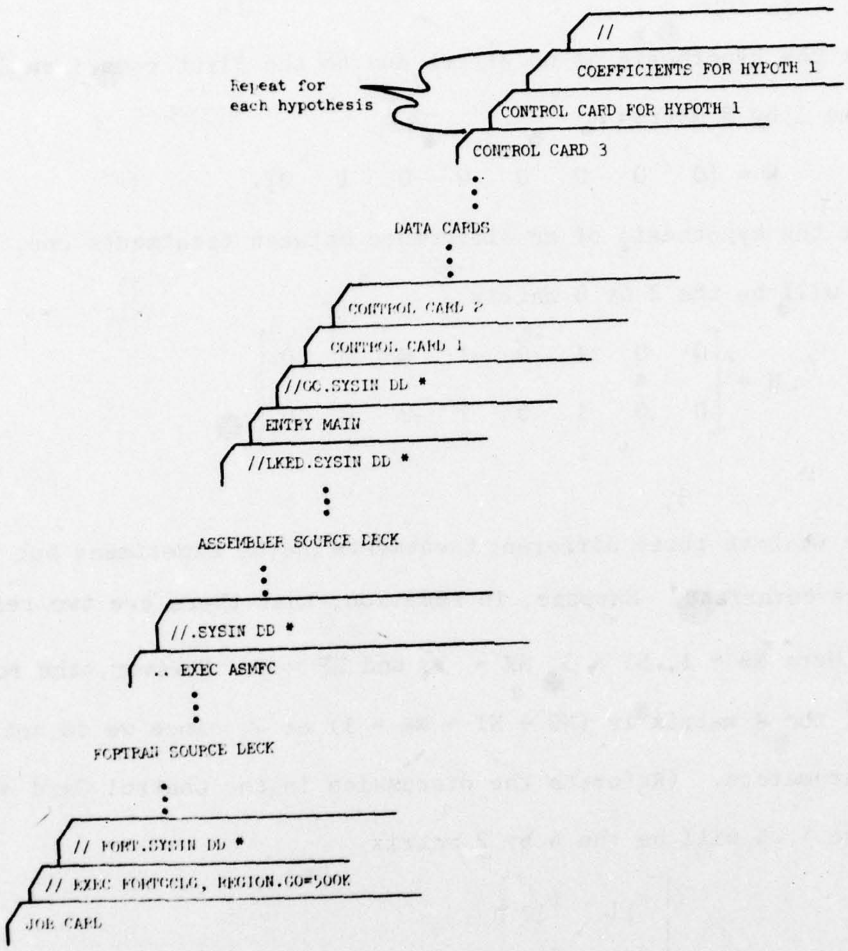
Suppose we have three different treatments in the experiment but only one block and one covariate. Suppose, in addition, that there are two response variables. Here NB = 1, NT = 3, NK = 1, and NP = 2. However, the row dimension of the B matrix is (NB + NT + NK - 1) or 4, since we do not require any block parameters. (Refer to the discussion in the Control Card subsection above.) B will be the 4 by 2 matrix

$$B = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \\ t_{31} & t_{32} \\ \beta_{11} & \beta_{12} \end{bmatrix}$$

The hypothesis matrix for testing "H_0: No Treatment Differences" will be the 2x4 matrix

$$H = \begin{bmatrix} 1 & -1 & 0 & 0 \\ 1 & 1 & -2 & 0 \end{bmatrix}.$$

The complete set of punched cards necessary to execute a job using the source program with a level G FORTRAN compiler are submitted to the card reader in the following order:



The form of the initial job card and the various job control cards may vary from one installation to another. The user should verify the validity of these with systems personnel at his particular computer center.

SECTION IV

A WORKED EXAMPLE

A sample problem will now be presented and the necessary programming steps illustrated. This data set was constructed to represent a set of results from a series of test shots involving two different metals from which projectiles were made (the blocks) and three different projectile shapes (the treatments). Each block/treatment combination was replicated five times, resulting in a total of 30 observations. Two concomitant variables were measured on each projectile. These were X_1=Initial Projectile Weight and X_2=Initial Projectile Velocity. The three dependent variables recorded were Y_1 = Residual Projectile Weight, Y_2 = Residual Projectile Velocity , and Y_3 = Plug Weight.

The data were generated using the model

$$Y_{ijk} = b_i + t_j + \beta_1 X_{1_{ijk}} + \beta_2 X_{2_{ijk}} + \varepsilon_{ijk}$$

where Y_{ijk} represents the $k\underline{th}$ replication of treatment j in block i for any one of the three response variates. For our problem i = 1,2; j = 1,2,3; k = 1,2,...,5. The disturbances were chosen from a table of random standard normal deviates (2). The values used for the model parameters were as shown in the following B matrix.

$$B = \begin{array}{c} \\ b_1 \\ b_2 \\ t_1 \\ t_2 \\ t_3 \\ \beta_1 \\ \beta_2 \end{array} \begin{array}{c} \begin{array}{ccc} Y_1 & Y_2 & Y_3 \end{array} \\ \begin{bmatrix} 0 & 0 & 0 \\ 2 & 20 & 0 \\ 10 & 8 & 0 \\ 10 & 8 & 0 \\ 20 & 20 & 4 \\ 8 & 0 & .005 \\ 0 & 7 & .01 \end{bmatrix} \end{array}$$

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The data resulting from this simulation were:

Observation	Block	Treatment	X_1	X_2	Y_1	Y_2	Y_3
1	1	1	110	710	98.0	504.4	7.3
2	1	1	110	710	97.5	503.2	5.2
3	1	1	112	695	98.2	494.5	8.3
4	1	1	111	705	100.0	501.1	8.2
5	1	1	112	690	100.1	490.9	8.1
6	1	2	110	710	98.4	504.6	8.3
7	1	2	109	705	95.5	501.2	8.8
8	1	2	107	700	94.6	497.0	10.5
9	1	2	111	700	99.3	498.8	9.5
10	1	2	112	710	98.9	504.3	7.5
11	1	3	116	810	110.7	586.4	8.1
12	1	3	115	770	112.4	558.9	8.5
13	1	3	116	790	113.3	572.6	8.9
14	1	3	116	800	110.6	581.1	8.7
15	1	3	117	790	115.3	572.9	7.4
16	2	1	109	705	98.3	522.8	6.6
17	2	1	112	705	101.0	521.3	8.3
18	2	1	111	690	99.1	510.0	6.3
19	2	1	110	700	99.8	517.2	8.3
20	2	1	111	710	103.1	524.3	8.4
21	2	2	112	700	100.9	517.6	5.8
22	2	2	112	690	100.5	510.5	7.2
23	2	2	114	695	103.1	514.6	6.2
24	2	2	112	700	99.5	517.3	7.4
25	2	2	113	705	102.0	522.9	8.8
26	2	3	115	795	114.2	597.1	12.3

27	2	3	116	800	114.8	598.6	12.5
28	2	3	117	795	115.9	598.0	12.7
29	2	3	116	790	116.0	593.0	12.3
30	2	3	117	805	115.2	602.4	12.4

For the purpose of a realistic example in which we have some missing observations among both the dependent and independent variables, we consider as missing the values of

Y_2 on observation 1

Y_3 and X_2 on observation 11

X_2 on observation 18

Y_2 and Y_3 on observation 24.

PREPARATION OF DATA CARDS

First we must select a value to use as the missing value code. Any negative number would suffice, as would zero. We have chosen D=50.0D0, a number intermediate in magnitude between Y_3 and the other X and Y variables. The data cards were punched as follows:

Columns 1-5 : The identification SAMPLE
Column 10: Block number
Column 12: Treatment number
Columns 13-16: X_1, in format F4.0
Columns 17-20: X_2, in format F4.0
Columns 22-25: Y_1, in format F4.1 (Decimal not punched)
Columns 27-30: Y_2, in format F4.1 (Decimal not punched)
Columns 31-34: Y_3, in format F4.1 (Decimal not punched)

For example, the first data card was, beginning in column 1:

SAMPLE 1 1 110 710 0980 0500 073

Note that the Y_2 value of 598.0 has been replaced by 50.0, since in this example we are treating it as a missing value.

PREPARATION OF CONTROL CARDS

Control Card 1:

To complete this card, we determine that for the present problem we have:

NP = 3

NT = 3

NB = 2

NK = 2

NN = 30

NMISS = 2

To provide a thorough look at the printout available from the program, we shall take every print option. Using the suggested values for EPS and IDGT, the first control card has the form, beginning in column 1:

```
003003002002030014002          1.00E-07  50.0D0  01010101010101
```

Control Card 2:

For this card, we may use any permissible FORTRAN format statement to read in the block number, treatment number, Y's and X's. One possibility for our data would be

(T10, I1, 1X, I1, T21, 2F5.1, F4.1, T14, F3.0, 1X, F3.0)

Control Card 3 and Subsequent Control Cards:

For this problem we shall test four hypotheses to illustrate the flexibility of this aspect of the program.

(1) H_o: No Block Differences

With only two blocks, the H matrix consists of one row which compares the two block effects. Recalling that for this problem the matrix of unknown parameters is

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \\ \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \end{bmatrix},$$

our H matrix is $H = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$. If we elect the overall test as well as the test on response variates two and three separately, the necessary control cards are:

```
00001NO BLK DIFF          01000101
0100-100
```

(2) H_o: No Treatment Differences

The H matrix for contrasting our three treatments requires two rows:

$$H = \begin{bmatrix} 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & -2 & 0 & 0 \end{bmatrix}$$

The necessary cards, electing the overall test as well as Y_1 and Y_2 separately, are:

```
00002NO TRT DIFF          01010100
000000000100-100
0000000001000100-200
```

(3) H_o: No Difference Between Treatments 1 and 2

If we elect the overall test as well as the test on each variate separately, the necessary cards are:

```
00001NO DIFF BETW TR 1&2 01010101
000000000100-100
```

(4) H_o: No Effect Due to Covariates

Electing the same test options as for the previous example, our control cards are

```
00002NO EFFECT COVARS    01010101
0000000000000000000000100
000000000000000000000000000100
```

These control cards for hypotheses must be preceded by control card 3, which for our problem will have a "4" punched in column 5, indicating that four hypotheses are to be tested.

THE PRINTED OUTPUT FROM THE PROGRAM

The program output, when all print options are exercised, has essentially 10 parts.

(1) Problem Dimensions:

This is the first page of the printout. It provides the user with the current program dimensions and dimensions for his particular job, as well as the print options chosen for the job.

(2) Listing of the Input Data:

Each observation is given with its block value, treatment value, dependent variables and independent variables in that order.

(3) The MAC Model Listing:

The response variables and complete design matrix are listed for the multivariate analysis of covariance model.

(4) The GMAC and MGMAC Model Listing:

These are given for each response variate separately, along with the rank of the corresponding design matrix.

(5) Sigma and Smoothed Sigma

The sigma matrix submitted to the subroutine SMOOTH is printed along with the smoothed sigma matrix which the subroutine returns.

(6) Sigma and Sigma Inverse

Sigma and its inverse, as computed by the LPSDOR subroutine, are given.

(7) The Matrix Modified Model

This is listed, showing the extra columns added to the design matrix to account for the missing values.

(8) The Groups of Observations with Different Patterns of Missing Values

These are the "S_j" sets referred to in Section II. The design matrices associated with these sets are used in the computation of the beta estimates and the Wald Statistics.

(9) Beta Values

The beta matrix of dimension (NB + NT + NK) by NP is given.

(10) Hypothesis Test Results

The hypothesis matrix and associated Wald Statistic are given for each of the hypotheses to be tested.

The listing of the computer printout for the sample problem follows in the remaining pages of this section.

It should be pointed out that it is normal for underflow errors to occur, particularly in large scale analyses. We might also add that the error code from LPSDOR is printed each time we call that subroutine; a successful call to LPSDOR results in an error code of zero.

```
PARAMETER VALUES READ FROM FIRST DATA CARD :


THE CURRENT VALUE BEING USED FOR THE MISSING CODE IS :      50.0000

THE VALUE OF IDGT SUPPLIED FOR USE IN LPSDOR SUBROUTINE IS :   14

THE VALUE OF EPS SUPPLIED FOR USE IN THE DMFGR SUBROUTINE IS :       .100000E-06

NUMBER OF MISSING VALUES IN COVARIATES :    2

MAX DIM RESP VECTOR:  7;CURRENT DIM RESP VECTOR:  3

MAX NUMB OBS:  100;CURRENT NUMB OBS:   30

MAX NUMB BLOCKS:     2;CURRENT NUMB BLOCKS:    2

MAX NUMB TRTS:     4;CURRENT NUMB TRTS:    3

MAX NUMB COVARS:     3;CURRENT NUMB COVARS:    2

MAX NUMB COLS IN MODIFIED DESIGN MATRIX:    10

CURRENT NUMBER COLS MAY BE SEEN IN LISTING OF MODIFIED DESIGN MATRIX TO FOLLOW LATER


PRINT OPTIONS CHOSEN FOR THIS PROGRAM: 0=NOPRINT,1=PRINT

PRINT OPTION FOR MAC MODEL :      1

PRINT OPTION FOR GMAC MODEL :      1

PRINT OPTION FOR MGMAC MODEL :      1

PRINT OPTION FOR SIGMA & ITS INVERSE :      1

PRINT OPTION FOR MATRIX MODIFIED MODEL :      1

PRINT OPTION FOR DEPENDENT VARIABLES AND DESIGN MATRIX FOR VARIOUS MISSING VALUE PATTERNS :      1

PRINT OPTION FOR BETA VALUES :      1
```

LISTING OF INPUT DATA

1	1	98.00	50.00	7.30	110.00	710.00
1	1	97.50	503.20	5.20	110.00	710.00
1	1	98.20	494.50	8.30	112.00	695.00
1	1	100.00	501.10	8.20	111.00	705.00
1	1	100.10	490.90	8.10	112.00	690.00
1	2	98.40	504.60	8.30	110.00	710.00
1	2	95.50	501.20	8.80	109.00	705.00
1	2	94.60	497.00	10.50	107.00	700.00
1	2	99.30	498.80	9.50	111.00	700.00
1	2	98.90	504.30	7.50	112.00	710.00
1	3	110.70	586.40	50.00	116.00	50.00
1	3	112.40	558.90	8.50	115.00	770.00
1	3	113.30	572.60	8.90	116.00	790.00
1	3	110.60	581.10	8.70	116.00	800.00
1	3	115.30	572.90	7.40	117.00	790.00
2	1	98.30	522.80	6.60	109.00	705.00
2	1	101.00	521.30	8.30	112.00	705.00
2	1	99.10	510.00	6.30	111.00	50.00
2	1	99.80	517.20	8.30	110.00	700.00
2	1	103.10	524.30	8.40	111.00	710.00
2	2	100.90	517.60	5.80	112.00	700.00
2	2	100.50	510.50	7.20	112.00	690.00
2	2	103.10	514.60	6.20	114.00	695.00
2	2	99.50	50.00	50.00	112.00	700.00
2	2	102.00	522.90	8.80	113.00	705.00
2	3	114.20	597.10	12.30	115.00	795.00
2	3	114.80	598.60	12.50	116.00	800.00
2	3	115.90	598.00	12.70	117.00	795.00
2	3	116.00	593.00	12.30	116.00	790.00

30 OBSERVATIONS HAVE BEEN READ FOR THE CURRENT DATA SET. DOES THIS AGREE WITH THE CURRENT # OBS GIVEN EARLIER?

THE VALUES OF Y AND A FOLLOW MAC MODEL

98.00	50.00	7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00
97.50	503.20	5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00
98.20	494.50	8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00
100.00	501.10	8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00
100.10	490.90	8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00
98.40	504.60	8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00
95.50	501.20	8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00
94.60	497.00	10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00
99.30	498.80	9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00
98.90	504.30	7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00
110.70	586.40	50.00	1.00	0.0	0.0	0.0	1.00	116.00	50.00
112.40	558.90	8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00
113.30	572.60	8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00
110.60	581.10	8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00
115.30	572.90	7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00
98.30	522.80	6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00
101.00	521.30	8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00
99.10	510.00	6.30	0.0	1.00	1.00	0.0	0.0	111.00	50.00
99.80	517.20	8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00
103.10	524.30	8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00
100.90	517.60	5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00
100.50	510.50	7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00
103.10	514.60	6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00
99.50	50.00	50.00	0.0	1.00	0.0	1.00	0.0	112.00	700.00
102.00	522.90	8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00
114.20	597.10	12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00
114.80	598.60	12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00
115.90	598.00	12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00
116.00	593.00	12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00

THE VALUES OF Y AND A FOR VARIATE 1 FOLLOW GMAC MODEL

98.00	1.00	0.0	1.00	0.0	0.0	110.00	710.00
97.50	1.00	0.0	1.00	0.0	0.0	110.00	710.00
98.20	1.00	0.0	1.00	0.0	0.0	112.00	695.00
100.00	1.00	0.0	1.00	0.0	0.0	111.00	705.00
100.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00
98.40	1.00	0.0	0.0	1.00	0.0	110.00	710.00
95.50	1.00	0.0	0.0	1.00	0.0	109.00	705.00
94.60	1.00	0.0	0.0	1.00	0.0	107.00	700.00
99.30	1.00	0.0	0.0	1.00	0.0	111.00	700.00
98.90	1.00	0.0	0.0	1.00	0.0	112.00	710.00
110.70	1.00	0.0	0.0	0.0	1.00	116.00	50.00
112.40	1.00	0.0	0.0	0.0	1.00	115.00	770.00
113.30	1.00	0.0	0.0	0.0	1.00	116.00	790.00
110.60	1.00	0.0	0.0	0.0	1.00	116.00	800.00
115.30	1.00	0.0	0.0	0.0	1.00	117.00	790.00
98.30	0.0	1.00	1.00	0.0	0.0	109.00	705.00
101.00	0.0	1.00	1.00	0.0	0.0	112.00	705.00
99.10	0.0	1.00	1.00	0.0	0.0	111.00	50.00
99.80	0.0	1.00	1.00	0.0	0.0	110.00	700.00
103.10	0.0	1.00	1.00	0.0	0.0	111.00	710.00
100.90	0.0	1.00	0.0	1.00	0.0	112.00	700.00
100.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00
103.10	0.0	1.00	0.0	1.00	0.0	114.00	695.00
99.50	0.0	1.00	0.0	1.00	0.0	112.00	700.00
102.00	0.0	1.00	0.0	1.00	0.0	113.00	705.00
114.20	0.0	1.00	0.0	0.0	1.00	115.00	795.00
114.80	0.0	1.00	0.0	0.0	1.00	116.00	800.00
115.90	0.0	1.00	0.0	0.0	1.00	117.00	795.00
116.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00

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THE VALUES OF Y AND A FOR VARIATE 1 FOLLOW   MGMAC MODEL

98.00	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
97.50	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
98.20	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
100.00	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
100.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
98.40	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
95.50	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
94.60	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
99.30	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
98.90	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
110.70	1.00	0.0	0.0	0.0	1.00	116.00	0.0	1.00	0.0
112.40	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
113.30	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0
110.60	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.30	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
98.30	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
101.00	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
99.10	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
99.80	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
103.10	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0
100.90	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
100.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
103.10	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
99.50	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
102.00	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
114.20	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
114.80	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.90	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
116.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0

THE RANK OF THE DESIGN MATRIX FOR VARIATE 1 FOR THE MGMAC MODEL IS 5

ERROR CODE FROM LPSDOR = 0

ERROR CODE FROM LPSDOR = 0

ERROR CODE FROM LPSDOR = 0

THE VALUES OF Y AND A FOR VARIATE 2 FOLLOW GMAC MODEL

503.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00
494.50	1.00	0.0	1.00	0.0	0.0	112.00	695.00
501.10	1.00	0.0	1.00	0.0	0.0	111.00	705.00
490.90	1.00	0.0	1.00	0.0	0.0	112.00	690.00
504.60	1.00	0.0	0.0	1.00	0.0	110.00	710.00
501.20	1.00	0.0	0.0	1.00	0.0	109.00	705.00
497.00	1.00	0.0	0.0	1.00	0.0	107.00	700.00
498.80	1.00	0.0	0.0	1.00	0.0	111.00	700.00
504.30	1.00	0.0	0.0	1.00	0.0	112.00	710.00
586.40	1.00	0.0	0.0	0.0	1.00	116.00	50.00
558.90	1.00	0.0	0.0	0.0	1.00	115.00	770.00
572.60	1.00	0.0	0.0	0.0	1.00	116.00	790.00
581.10	1.00	0.0	0.0	0.0	1.00	116.00	800.00
572.90	1.00	0.0	0.0	0.0	1.00	117.00	790.00
522.80	0.0	1.00	1.00	0.0	0.0	109.00	705.00
521.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00
510.00	0.0	1.00	1.00	0.0	0.0	111.00	50.00
517.20	0.0	1.00	1.00	0.0	0.0	110.00	700.00
524.30	0.0	1.00	1.00	0.0	0.0	111.00	710.00
517.60	0.0	1.00	0.0	1.00	0.0	112.00	700.00
510.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00
514.60	0.0	1.00	0.0	1.00	0.0	114.00	695.00
522.90	0.0	1.00	0.0	1.00	0.0	113.00	705.00
597.10	0.0	1.00	0.0	0.0	1.00	115.00	795.00
598.60	0.0	1.00	0.0	0.0	1.00	116.00	800.00
598.00	0.0	1.00	0.0	0.0	1.00	117.00	795.00
593.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00
602.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00

THE VALUES OF Y AND A FOR VARIATE 2 FOLLCW   MGMAC MODEL

503.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
494.50	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
501.10	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
490.90	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
504.60	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
501.20	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
497.00	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
498.80	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
504.30	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
586.40	1.00	0.0	0.0	0.0	1.00	116.00	0.0	1.00	0.0
558.90	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
572.60	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0
581.10	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0	0.0
572.90	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
522.80	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
521.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
510.00	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
517.20	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
524.30	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0
517.60	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
510.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
514.60	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
522.90	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
597.10	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
598.60	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
598.00	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
593.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0
602.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00	0.0	0.0

THE RANK OF THE DESIGN MATRIX FOR VARIATE 2 FOR THE MGMAC MODEL IS 5

ERROR CODE FROM LPSDOR =   0

ERROR CODE FROM LPSDOR =   0

THE VALUES OF Y AND A FOR VARIATE 3 FOLLOW GMAC MODEL

7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00
5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00
8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00
8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00
8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00
8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00
8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00
10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00
9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00
7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00
8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00
8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00
8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00
7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00
6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00
8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00
6.30	0.0	1.00	1.00	0.0	0.0	111.00	50.00
8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00
8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00
5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00
7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00
6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00
8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00
12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00
12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00
12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00
12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00
12.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00

THE VALUES OF Y AND A FOR VARIATE 3 FOLLCW MGMAC MODEL

7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0
5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0
8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0
8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0
8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0
8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0
8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0
10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0
9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0
7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0
8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0
8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0
8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0
7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0
6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0
8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0
6.30	0.0	1.00	1.00	0.0	0.0	111.00	0.0	1.00
8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0
8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0
5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0
7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0
6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0
8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0
12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0
12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0
12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0
12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0
12.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00	0.0

THE RANK OF THE DESIGN MATRIX FOR VARIATE 3 FOR THE MGMAC MODEL IS 5

```
ERROR CODE FROM LPSDOR =        0


INPUT MATRIX TO SMOOTH
     1.0281164          -.11701501          .19631602
     -.11701501          .69946443          .11176522
      .19631602          .11176522         2.2882109


MATRIX OUTPUT BY SMOOTH
     1.0281164          -.11701501          .19631602
     -.11701501          .69946443          .11176522
      .19631602          .11176522         2.2882109



THE VALUE OF SIGMA FOLLOWS


  1.02812      -.117015      .196316

  -.117015      .699464      .111765

   .196316      .111765     2.28821

ERROR CODE FROM LPSDOR =        0




THE VALUE OF SIGMA INVERSE FOLLOWS


  1.01196        .184607      -.958379D-01

   .184607      1.47459       -.878630D-01

 -.958379D-01  -.878630D-01    .449537
```

THE VALUES OF Y AND A FOLLOW MATRIX MODIFIED MODEL

98.00	50.00	7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
97.50	503.20	5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
98.20	494.50	8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
100.00	501.10	8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
100.10	490.90	8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
98.40	504.60	8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
95.50	501.20	8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
94.60	497.00	10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
99.30	498.80	9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
98.90	504.30	7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
110.70	586.40	50.00	1.00	0.0	0.0	0.0	1.00	116.00	0.0	1.00	0.0
112.40	558.90	8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
113.30	572.60	8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0
110.60	581.10	8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.30	572.90	7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
98.30	522.80	6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
101.00	521.30	8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
99.10	510.00	6.30	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
99.80	517.20	8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
103.10	524.30	8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0

100.90	517.60	5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
100.50	510.50	7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
103.10	514.60	6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
99.50	50.00	50.00	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
102.00	522.90	8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
114.20	597.10	12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
114.80	598.60	12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.90	598.00	12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
116.00	593.00	12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0

```
****** DEPENDENT VARIABLES AND DESIGN MATRIX FOR THE VARIOUS GROUPS CORRESPONDING TO DIFFERENT PATTERNS OF MISSING VALUES
**** THERE ARE     7 DIFFERENT POSSIBLE GROUPS NUMBERED FROM 1 TO    7 THOUGH IN GENERAL NOT ALL GROUPS WILL APPEAR

*** WHICH ONES OCCUR DEPENDS ON THE PATTERN OF MISSING VALUES.HOWEVER THE TOTAL # OBSERVATIONS IN ALL GROUPS MUST EQUAL NN
THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     4 WHICH HAS     1 OBSERVATIONS ON     1 VARIATES


   99.50    50.00    50.00     0.0      1.00     0.0      1.00     0.0    112.00   700.00     0.0      0.0
THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     5 WHICH HAS     1 OBSERVATIONS ON     2 VARIATES


   98.00    50.00     7.30     1.00     0.0      1.00     0.0      0.0    110.00   710.00     0.0      0.0

ERROR CODE FROM LPSDOR =       0

THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     6 WHICH HAS     1 OBSERVATIONS ON     2 VARIATES


  110.70   586.40    50.00     1.00     0.0      0.0      0.0      1.00   116.00     0.0      1.00     0.0

ERROR CODE FROM LPSDOR =       0

THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     7 WHICH HAS    27 OBSERVATIONS ON     3 VARIATES
```

97.50	503.20	5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
98.20	494.50	8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
100.00	501.10	8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
100.10	490.90	8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
98.40	504.60	8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
95.50	501.20	8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
94.60	497.00	10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
99.30	498.80	9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
98.90	504.30	7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
112.40	558.90	8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
113.30	572.60	8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0

115.30	572.90	7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
98.30	522.80	6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
101.00	521.30	8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
99.10	510.00	6.30	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
99.80	517.20	8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
103.10	524.30	8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0
100.90	517.60	5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
100.50	510.50	7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
103.10	514.60	6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
102.00	522.90	8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
114.20	597.10	12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
114.80	598.60	12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.90	598.00	12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
116.00	593.00	12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0
115.20	602.40	12.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00	0.0	0.0

```
ERROR CODE FROM LPSDOR =       0

IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D625F7642 . REGISTER CONTAINED   7A10000000000000

TRACEBACK  ROUTINE  CALLED FROM ISN   REG. 14    REG. 15    REG.  0    REG.  1

           LSVALR             0018    625F1F24   005F2328   00000000   005F1B58

           LPSDOR             0554    625EAF56   005F1A20   00000008   005912C4

           MAIN                       00C08AA2   01590A78   00D5F378   0060EFF8

ENTRY POINT=  01590A78

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D625F759E . REGISTER CONTAINED   7A10000000000000

TRACEBACK  ROUTINE  CALLED FROM ISN   REG. 14    REG. 15.   REG.  0    REG.  1

           LSVALR             0018    625F1F24   005F2328   00000000   005F1B58

           LPSDOR             0554    625EAF56   005F1A20   00000008   005912C4

           MAIN                       00C08AA2   01590A78   00D5F378   0060EFF8

ENTRY POINT=  01590A78

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D625F7642 . REGISTER CONTAINED   7FFFFFFE00000010
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        LSVALR            0018     625F1F24   005F2328   00000000   005F1B58
        LPSDOR            0554     625EAF56   005F1A20   00000008   005912C4
        MAIN                       00C08AA2   01590A78   00D5F378   0060EFF8
ENTRY POINT=  01590A78
STANDARD FIXUP TAKEN . EXECUTION CONTINUING
IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D925F7430 . REGISTER CONTAINED   F9FFFFFE0000000
TRACEBACK  ROUTINE   CALLED FROM ISN   REG. 14   REG. 15   REG.  0   REG.  1
        LSVALR            0018     625F1F24   005F2328   00000000   005F1B58
        LPSDOR            0554     625EAF56   005F1A20   00000008   005912C4
        MAIN                       00008AA2   01590A78   00D5F378   0060EFF8
ENTRY POINT=  01590A78
STANDARD FIXUP TAKEN . EXECUTION CONTINUING
IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D925F7420 . REGISTER CONTAINED   72FFFFFF40000024
TRACEBACK  ROUTINE   CALLED FROM ISN   REG. 14   REG. 15   REG.  0   REG.  1
        LSVALR            0018     625F1F24   005F2328   00000000   005F1B58
        LPSDOR            0554     625EAF56   005F1A20   00000008   005912C4
        MAIN                       00008AA2   01590A78   00D5F378   0060EFF8
ENTRY POINT=  01590A78
STANDARD FIXUP TAKEN . EXECUTION CONTINUING

ERROR CODE FROM LPSDOR =      0
```

****** LISTING OF PARAMETER ESTIMATES IN THE ORDER : BLOCKS, TRTS, REGRESSION COEFFICIENTS DOWN THE PAGE ******

VAR#1	VAR#2	VAR#3	VAR#4	VAR#5	VAR#6	VAR#7
3.43125	3.49547	11.0229				
5.32569	23.7083	12.1166				
-.200726	4.59276	7.10731				
-.980883	4.81954	7.69098				
9.93823	17.7915	8.34121				
.897697	.876527D-01	-.347398				
-.563294D-02	.685404	.391009D-01				

****** HYPOTHESIS TESTING SECTION ******

4 HYPOTHESIS MATRICES SHALL BE USED, IN TURN, FOR COMPUTING CHI SQUARE STATISTICS

EACH MATRIX SHOULD HAVE 7 COLUMNS AS FOLLOWS :

THE FIRST 2 COLUMNS CORRESPOND TO BLOCK PARAMETERS
THE NEXT 3 COLUMNS CORRESPOND TO TREATMENT PARAMETERS
THE LAST 2 COLUMNS CORRESPOND TO COVARIATE COEFFICIENTS

```
**** LISTING OF HYPOTHESIS MATRIX     1 FCLLOWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO BLK DIFF


  1.00 -1.00  0.0   0.0   0.0   0.0   0.C

ROW( 1):  1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ERROR CODE FRCM LPSDOR =       0

THE WALD STATISTIC FCR HYPOTHESIS    1 FOR ALL     3 RESPONSE VARIABLES SIMULTANEOUSLY IS :        3489.4482

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH     3 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  1 WITH ID: NO BLK DIFF          ******

  *** THE OPTIONS FOR THE   3 INDIVIDUAL VARIATES ARE:   0  1  1

 ERROR CODE FROM LPSDOR =       0

 THE WALD STATISTIC FOR HYPOTHESIS     1 RESTRICTED TO RESPONSE VARIATE    2 ONLY IS :        3310.2092

 ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM


 ERROR CODE FROM LPSDOR =       0

 THE WALD STATISTIC FOR HYPOTHESIS     1 RESTRICTED TO RESPONSE VARIATE    3 ONLY IS :           3.0643

 ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM
```

```
**** LISTING OF HYPOTHESIS MATRIX    2 FCLLGWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO TRT DIFF


  0.0   0.0   1.00 -1.00  0.0   0.0   0.0

  0.0   0.0   1.00  1.00 -2.00  0.0   0.C

ROW( 1):   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):   0.0   0.0   1.00  1.00 -2.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 4):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00  1.00 -2.00  0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 5):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1.00 -1.00  0.0   0.0   0.0   0.0   0.0

ROW( 6):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1.00  1.00 -2.00  0.0   0.0   0.0   0.0

ERROR CODE FROM LPSDOR =       0


THE WALD STATISTIC FOR HYPOTHESIS    2 FOR ALL    3 RESPONSE VARIABLES SIMULTANEOUSLY IS :          63.8415

ITS ASYMPTOTIC DISTRILUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    6 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  2 WITH ID: NO TRT DIFF            ******

  *** THE OPTIONS FOR THE   3 INDIVIDUAL VARIATES ARE:   1  1  0

 ERROR CODE FRCM LPSDOR =       0

 THE WALD STATISTIC FOR HYPOTHESIS    2 RESTRICTED TO RESPONSE VARIATE    1 ONLY IS :          18.4689

 ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPCTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM

 ERROR CODE FROM LPSDOR =       0

 THE WALD STATISTIC FOR HYPOTHESIS    2 RESTRICTED TO RESPONSE VARIATE    2 ONLY IS :          35.9924

 ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM
```

```
**** LISTING OF HYPOTHESIS MATRIX     3 FOLLOWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO DIFF BETW TR 1&2

  0.0   0.0   1.00 -1.00  0.0   0.0   0.0

ROW( 1):   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1.00 -1.00  0.0   0.0   0.0   0.0   0.0

ERROR CODE FROM LPSDOR =      0
```



```
THE WALD STATISTIC FOR HYPOTHESIS    3 FOR ALL     3 RESPONSE VARIABLES SIMULTANEOUSLY IS :           3.8482

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH     3 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  3 WITH ID: NO DIFF BETW TR 1&2  ******


 *** THE OPTIONS FOR THE    3 INDIVIDUAL VARIATES ARE:   1  1  1

ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     3 RESTRICTED TO RESPONSE VARIATE     1 ONLY IS :          2.7376

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH     1 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     3 RESTRICTED TO RESPONSE VARIATE     2 ONLY IS :          0.3090

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH     1 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     3 RESTRICTED TO RESPONSE VARIATE     3 ONLY IS :          0.6594

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH     1 DEGREES OF FREEDOM
```

```
**** LISTING OF HYPOTHESIS MATRIX    4 FCLLOWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO EFFECT COVARS

  0.0   0.0   0.0   0.0   0.0   1.00  0.C

  0.0   0.0   0.0   0.0   0.0   0.0   1.00

ROW( 1):   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):   0.0   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 4):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 5):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   1.00  0.0   0.0   0.0

ROW( 6):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   1.00  0.0   0.0

ERROR CODE FROM LPSDOR =        0

THE WALD STATISTIC FOR HYPOTHESIS    4 FOR ALL    3 RESPONSE VARIABLES SIMULTANEOUSLY IS :        1043.5930

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    6 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  4 WITH ID: NO EFFECT COVARS     ******

 *** THE OPTIONS FOR THE    3 INDIVIDUAL VARIATES ARE:   1  1  1

ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     4 RESTRICTED TO RESPONSE VARIATE     1 ONLY IS :          36.6924

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     4 RESTRICTED TO RESPONSE VARIATE     2 ONLY IS :         985.3437

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     4 RESTRICTED TO RESPONSE VARIATE     3 ONLY IS :           3.9067

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM
```

```
SUMMARY OF ERRORS FOR THIS JOB   ERROR NUMBER   NUMBER OF ERRORS
                                     208               8
```

REFERENCES

1. Natrella, M.G. (1963). Experimental Statistics. NBS Handbook 91, U.S. Department of Commerce.

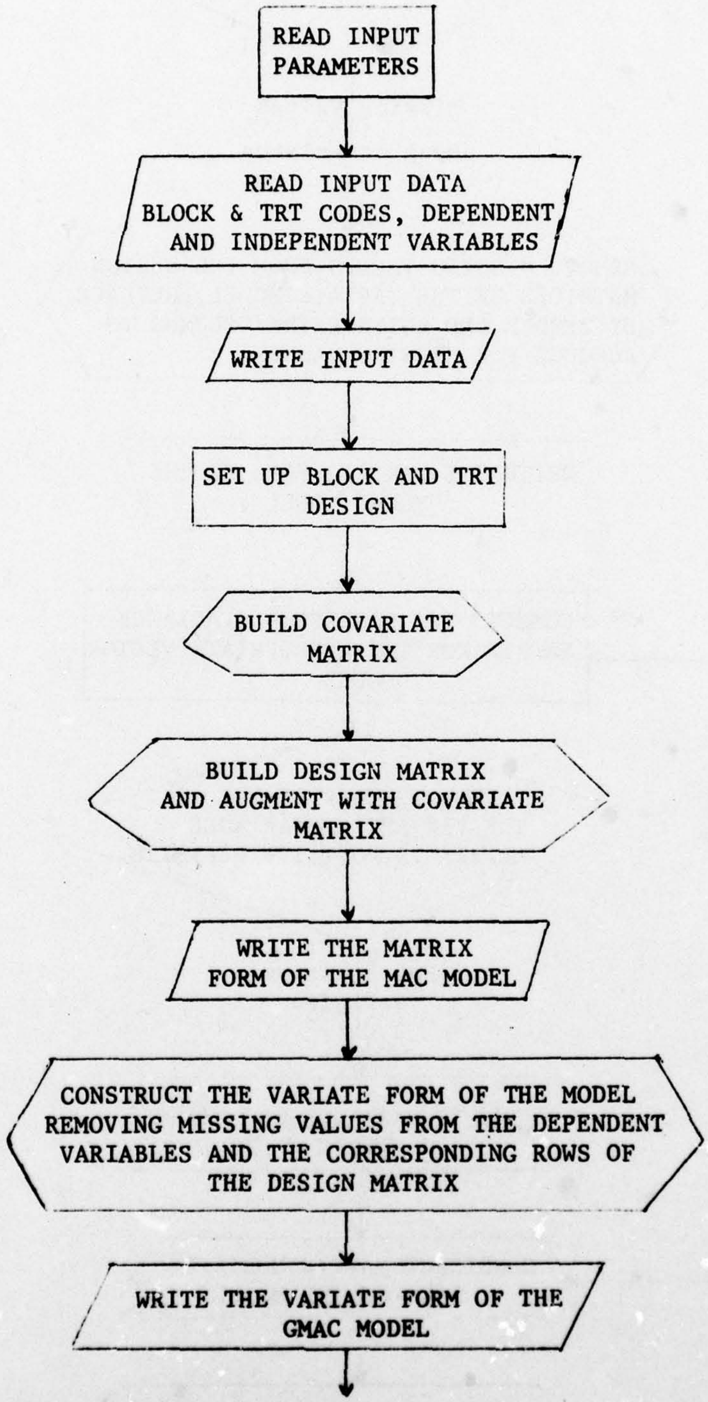
2. Srivastava, J.N. (1968). On a General Class of Designs for Multi-response Experiments, Ann. Math. Stat., 39: 1825-1843.

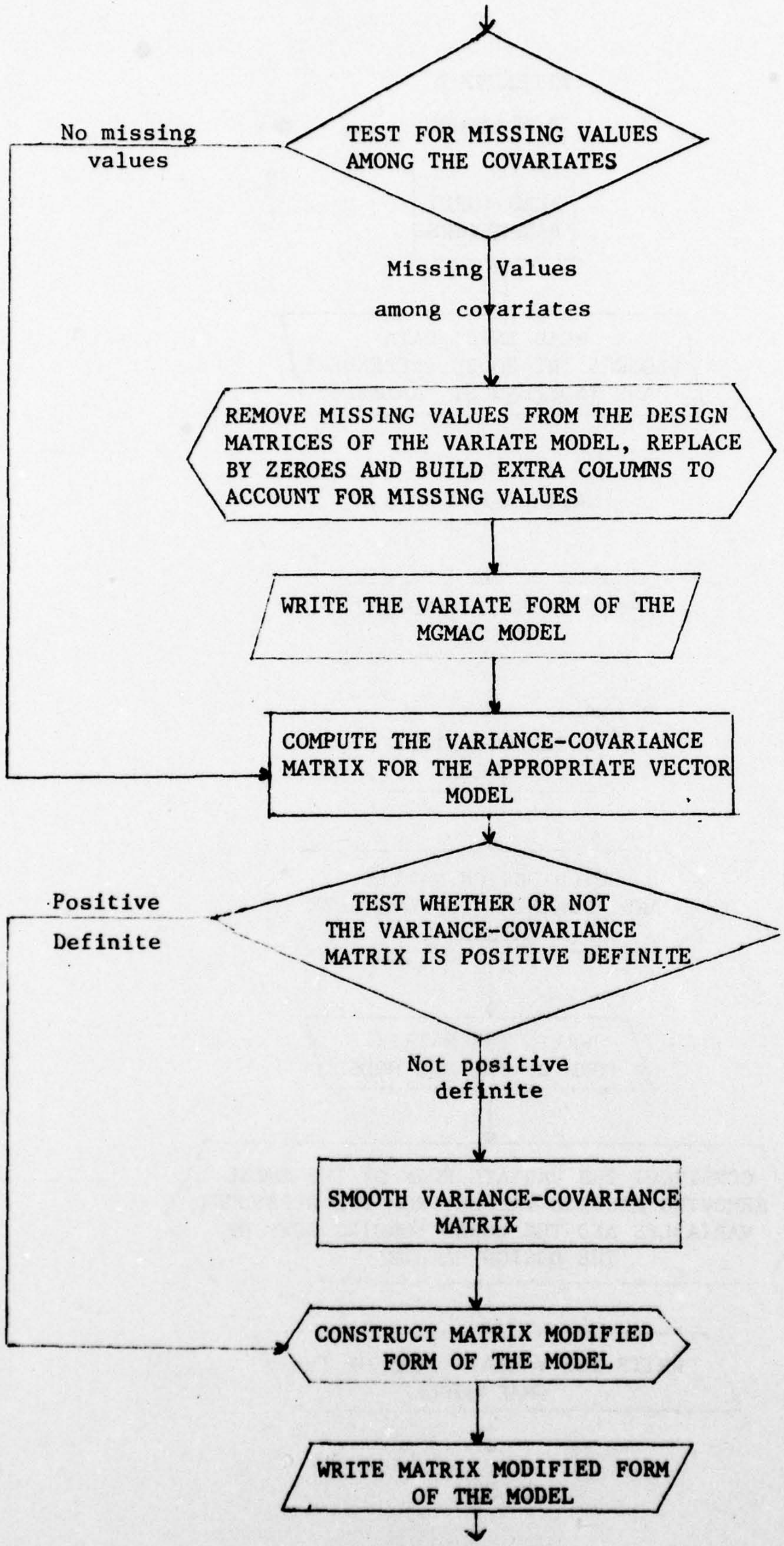
3. Haitovsky, Y. (1968). Missing Data in Regression Analysis, J. Roy. Stat Society, Series B., 30: 67-82.

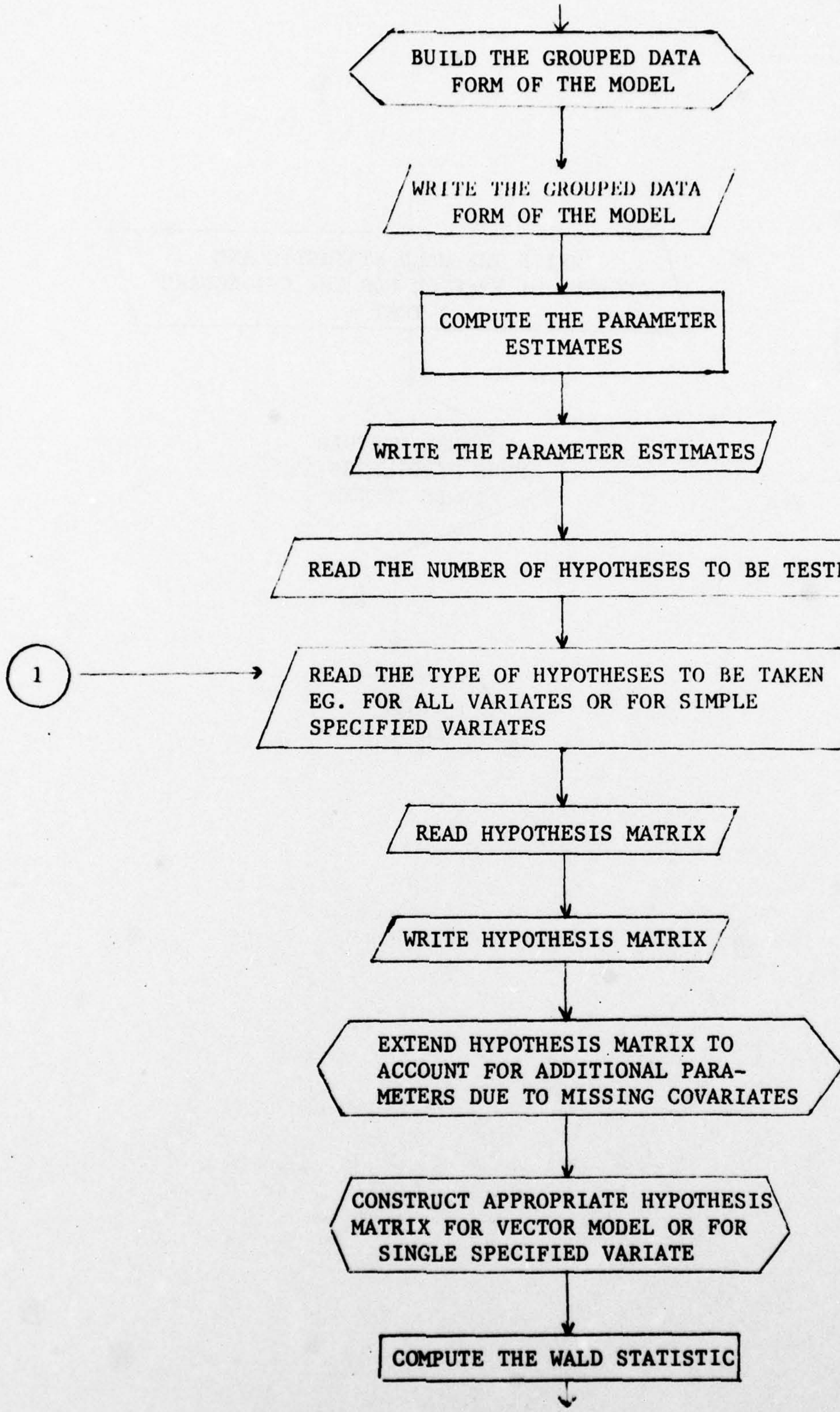
4. Kleinbaum, D.G. (1973). Testing Linear Hypotheses in Generalized Multivariate Linear Models, Comm. in Stat., 1(5), 433-457.

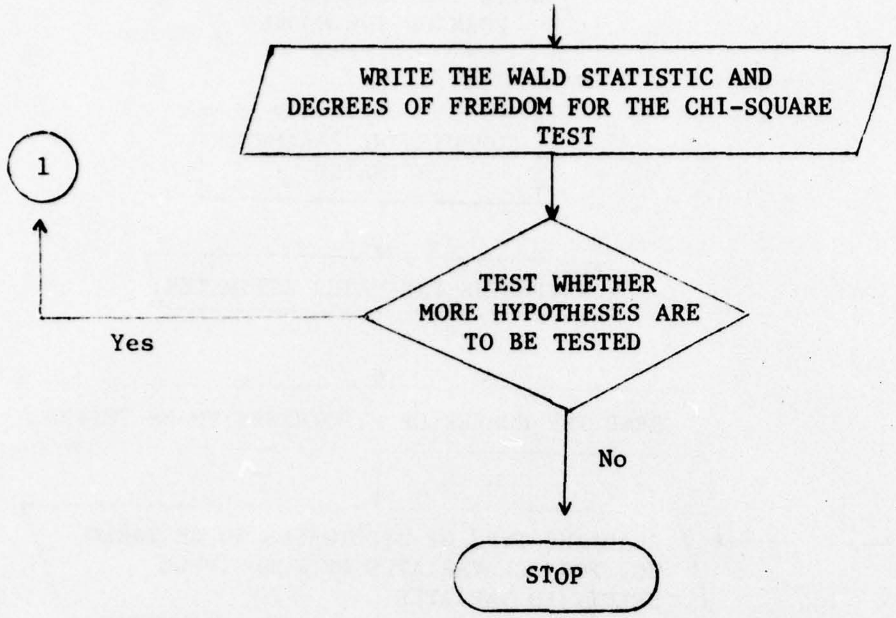
APPENDIX A

FLOW CHART




No missing values
TEST FOR MISSING VALUES AMONG THE COVARIATES
Missing Values among covariates
REMOVE MISSING VALUES FROM THE DESIGN MATRICES OF THE VARIATE MODEL, REPLACE BY ZEROES AND BUILD EXTRA COLUMNS TO ACCOUNT FOR MISSING VALUES
WRITE THE VARIATE FORM OF THE MGMAC MODEL
COMPUTE THE VARIANCE-COVARIANCE MATRIX FOR THE APPROPRIATE VECTOR MODEL
Positive Definite
TEST WHETHER OR NOT THE VARIANCE-COVARIANCE MATRIX IS POSITIVE DEFINITE
Not positive definite
SMOOTH VARIANCE-COVARIANCE MATRIX
CONSTRUCT MATRIX MODIFIED FORM OF THE MODEL
WRITE MATRIX MODIFIED FORM OF THE MODEL


BUILD THE GROUPED DATA FORM OF THE MODEL
WRITE THE GROUPED DATA FORM OF THE MODEL
COMPUTE THE PARAMETER ESTIMATES
WRITE THE PARAMETER ESTIMATES
READ THE NUMBER OF HYPOTHESES TO BE TESTED
1
READ THE TYPE OF HYPOTHESES TO BE TAKEN EG. FOR ALL VARIATES OR FOR SIMPLE SPECIFIED VARIATES
READ HYPOTHESIS MATRIX
WRITE HYPOTHESIS MATRIX
EXTEND HYPOTHESIS MATRIX TO ACCOUNT FOR ADDITIONAL PARAMETERS DUE TO MISSING COVARIATES
CONSTRUCT APPROPRIATE HYPOTHESIS MATRIX FOR VECTOR MODEL OR FOR SINGLE SPECIFIED VARIATE
COMPUTE THE WALD STATISTIC


WRITE THE WALD STATISTIC AND DEGREES OF FREEDOM FOR THE CHI-SQUARE TEST
1
TEST WHETHER MORE HYPOTHESES ARE TO BE TESTED
Yes
No
STOP

APPENDIX B

PROGRAM LISTING

In the subsequent pages, a listing of the FORTRAN source program is given. This is the program which was used to provide the printout for the sample problem in Section IV, Volume II.

We do not list the subroutines used from the Scientific Subroutine Package nor the International Mathematical and Statistical Library. These are available in the appropriate manuals.

```
                 C
0001                   REAL*8 A(100,10),AJA(10,10),AS(100,10),B(7,7),BB(100, 7),BETA( 70)
                      *,BLK(100,2),BS(7,7),BT(100,6),BSIG(7,7),BSIGB(7,7),BSIGIB(7,7),
                      #BBSIGI(7,7),BETAMX(26,7)
                 C
0002                   INTEGER*4 IBLK(100),ITRT(100),IR(7),IRR(7,7),IN(100,7),IND(100),
                      %NCJ(127),NCL(127),NCMK(9),NCM(7,9),NCMC(7,7,9),NCTC(7,7),NCT(7),
                      @NMA(7),NMAC(7,7),NUMRCW(9)
0003                   INTEGER*4 IROW(26),ICOL(26),IPRKOD(7),KDRESP(7)
                 C
0004                   REAL*4 FMT(20),EPS,HYPID(5)
                 C
0005                   REAL*8 F(100,10),W,D,SIGI,H(56, 70),HPRNV(56, 70),HPRH(56,56),
                      %HBETA(56),HBETAP(56),HP(8, 70),PROD2(70,70)
                 C
0006                   REAL*8 RV( 70),RSS(10,10),RSSS(100),S(100,10),T( 5180),SIG(7,7),
                      #SIGINV(7,7),TRT(100,4),U(100,100),V(100)
                 C
                 C
0007                   REAL*8 X(100,3),Y(100,7),YYS(100,7),YS(100,7),Z(100),ZT(100),
                      <ZY(100),ZZ(7)
                 C
                 C *** ARRAYS WHICH MAY HAVE TO BE REDIMENSIONED TO HANDLE A LARGER #
                 C *** OF MISSING VALUES ARE : A,AJA,AS,BETA,BETAMX,F,H,HPRNV,PROD2,RV,
                 C *** RSS,RSSS,S,T,NCMK,NCM,NCMC,IROW,ICOL
                 C
                 C ***    CURRENT DIMENSIONS OF ARRAYS; INCREASE THESE AND THE CORRESPONDING
                 C ***    DIMENSIONS TO INCREASE THE CAPACITY OF THE PROGRAM
                 C
0008                   NPDIM = 7
0009                   NNDIM = 100
0010                   NBDIM = 2
0011                   NTDIM = 4
0012                   NKDIM=3
0013                   NADIM = 10
0014                   NFDIM = 10
0015                   NPROD=70
0016                   NHPRHD=56
                 C
                 C
                 C     EQUIVALENCE (T(1),AS(1)),(X(1),S(1)),(H(1),U(1))
                 C
0017                   DATA B/49*0.0D0/,BLK/200*0.0D0/,H/3920*0.0D0/,IN/700*1/,
                      @PROD2/4900*0.0D0/,RV/70*0.0D0/,TRT/400*0.0D0/
0018                   DATA RSS/100*0.0D0/
                 C
                 C   NP EQUALS THE NUMBER OF DEPENDENT VARIABLES
                 C   NT EQUALS THE NUMBER OF TREATMENTS
                 C   NB EQUALS THE NUMBER OF BLOCKS
                 C   NK EQUALS THE NUMBER INDEPENDENT VARIABLES
                 C
                 C READ INPUT DATA
                 C
0019                   READ(5,1) NP,NT,NB,NK,NN,IDGT,NMISS,EPS,D,IPRKOD
0020                 1 FORMAT(7I3,T30,E10.0,D10.0,7I2)
0021                   WRITE(6,9901)
0022              9901 FORMAT('1','PARAMETER VALUES READ FROM FIRST DATA CARD : ',////)
0023                   WRITE(6,9909) D
```

```
0024          9909 FORMAT('0','THE CURRENT VALUE BEING USED FOR THE MISSING CODE IS :
                  <',G16.6)
0025               WRITE(6,9910) ICGT
0026          9910 FORMAT('0','THE VALUE OF IDGT SUPPLIED FOR USE IN LPSDOR SUBROUTIN
                  *E IS :',I5)
0027               WRITE(6,9911) EPS
0028          9911 FORMAT('0','THE VALUE OF EPS SUPPLIED FOR USE IN THE DMFGR SUBROUT
                  *INE IS : ',G16.6)
0029               WRITE(6,9902) NMISS
0030          9902 FORMAT('0','NUMEER OF MISSING VALUES IN COVARIATES :',I5)
0031               WRITE(6,9903) NFDIM,NP
0032          9903 FORMAT('0','MAX CIM RESP VECTOR:',I3,';CURRENT DIM RESP VECTOR:',
                  #I3)
0033               WRITE(6,9904) NNDIM,NN
0034          9904 FORMAT('0','MAX NUMB OBS:',I5,';CURRENT NUMB OBS:',I5)
0035               WRITE(6,9905) NBDIM,NB
0036          9905 FORMAT('0','MAX NUMB BLOCKS:',I5,';CURRENT NUMB BLOCKS:',I5)
0037               WRITE(6,9906) NTCIM,NT
0038          9906 FORMAT('0','MAX NUMB TRTS:',I5,';CURRENT NUMB TRTS:',I5)
0039               WRITE(6,9907) NKCIM,NK
0040          9907 FORMAT('0','MAX NUMB COVARS:',I5,';CURRENT NUMB COVARS:',I5)
0041               WRITE(6,9908) NACIM
0042          9908 FORMAT('0','MAX NUMB COLS IN MODIFIED DESIGN MATRIX:',I5,/,/,1X,
                  #'CURRENT NUMBER CCLS MAY BE SEEN IN LISTING OF MODIFIED DESIGN MAT
                  URIX TO FOLLOW LATER',//)
0043               WRITE(6,9770)
0044          9770 FORMAT('0','PRINT OPTICNS CHOSEN FOR THIS PROGRAM: 0=NOPRINT,1=PRI
                  #NT')
0045          9769 FORMAT('0','PRINT CPTICN FOR MAC MODEL : ',I5)
0046          9768 FORMAT('0','PRINT OPTION FOR GMAC MODEL : ',I5)
0047          9767 FORMAT('C','PRINT OPTION FOR MGMAC MODEL : ',I5)
0048          9766 FORMAT('0','PRINT CPTICN FOR SIGMA & ITS INVERSE : ',I5)
0049          9765 FORMAT('0','PRINT OPTICN FOR MATRIX MODIFIED MODEL : ',I5)
0050          9764 FORMAT('0','PRINT CPTICN FOR DEPENDENT VARIABLES AND DESIGN MATRIX
                  * FOR VARIOUS MISSING VALUE PATTERNS : ',I5)
0051          9763 FORMAT('0','PRINT OPTION FOR BETA VALUES : ',I5)
0052               WRITE(6,9769) IFRKOD(1)
0053               WRITE(6,9768) IFRKOD(2)
0054               WRITE(6,9767) IFRKOD(3)
0055               WRITE(6,9766) IFRKCD(4)
0056               WRITE(6,9765) IFRKOD(5)
0057               WRITE(6,9764) IFRKOD(6)
0058               WRITE(6,9763) IFRKOD(7)
0059               READ(5,2) FMT
0060             2 FORMAT(20A4)
              C
              C    WRITE INPUT DATA
              C
0061               WRITE(6,3)
0062             3 FORMAT(1H1,'LISTING OF INPUT DATA',///)
0063               IF(NB.LE.1.AND.NT.LE.1) GO TO 11
0064               IF(NB.LE.1) GO TC 29
0065               IF(NT.LE.1) GO TC 28
0066               IKKK=0
0067               DO 4 I=1,NN
0068               READ(5,FMT) IBLK(I),ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
0069               IKKK=IKKK+1
0070               WRITE(6,5) IBLK(I),ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
```

```
0071          5 FORMAT(1H0,2I4,15F8.2)
        C
        C     SET UP BLOCK DESIGN
        C
0072            DO 7 II=1,NB
0073            IF(IBLK(I).EQ.II) BLK(I,II)=1.0D0
0074          7 CONTINUE
        C
        C     SET UP TREATMENT DESIGN
        C
0075            DO 6 II=1,NT
0076            IF(ITRT(I).EQ.II) TRT(I,II)=1.0D0
0077          6 CONTINUE
0078          4 CONTINUE
0079            WRITE(6,9798) IKKK
0080       9798 FORMAT('0',//,'C',I5,' OBSERVATIONS HAVE BEEN READ FOR THE CURRENT
               # DATA SET. DOES THIS AGREE WITH THE CURRENT # OBS GIVEN EARLIER?')
        C
        C     BUILD DESIGN MATRIX BY AUGMENTING BLOCKS, TREATMENTS AND COVARIATES
        C
0081            CALL ARRAY(2,NN,NB,NNDIM,NBDIM,BLK,BLK)
0082            CALL ARRAY(2,NN,NT,NNDIM,NTDIM,TRT,TRT)
0083            CALL CTIE(BLK,TRT,BT,NN,NB,0,0,NT)
0084            NBT=NB+NT
0085            GO TO 25
0086         11 IKKK=0
0087            DO 41 I=1,NN
0088            READ(5,FMT) (Y(I,J),J=1,NP),(X(I,J),J=1,NK)
0089            IKKK=IKKK+1
0090            WRITE(6,95) (Y(I,J),J=1,NP),(X(I,J),J=1,NK)
0091         95 FORMAT(1H0,15F8.2)
0092         41 CONTINUE
0093            WRITE(6,9798) IKKK
0094            DO 22 I=1,NN
0095            DO 22 K=1,NK
0096            A(I,K)=X(I,K)
0097         22 CONTINUE
0098            NM = NK
0099            GO TO 26
0100         29 IKKK=0
0101            DO 40 I=1,NN
0102            READ(5,FMT) ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
0103            IKKK=IKKK+1
0104            WRITE(6,45) ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
0105         45 FORMAT(1H0,I4,15F8.2)
0106            DO 60 II=1,NT
0107            IF(ITRT(I).EQ.II) TRT(I,II)=1.0D0
0108         60 CONTINUE
0109         40 CONTINUE
0110            WRITE(6,9798) IKKK
0111            DO 24 II=1,NN
0112            DO 24 K=1,NT
0113            BT(II,K) = TRT(II,K)
0114         24 CONTINUE
0115            CALL ARRAY(2,NN,NT,NNDIM,NTDIM,BT,BT)
0116            NBT = NT
0117            GO TO 25
0118         28 IKKK=0
```

```
      DO 42 I=1,NN
      READ(5,FMT) IBLK(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
      IKKK=IKKK+1
      WRITE(6,46) IBLK(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
   46 FORMAT(1H0,I4,15F8.2)
      DO 61 II=1,NB
      IF(IBLK(I).EQ.II) BLK(I,II) = 1.0D0
   61 CONTINUE
   42 CONTINUE
      WRITE(6,9798) IKKK
      DO 27 I=1,NN
      DO 27 K=1,NB
      BT(I,K)=BLK(I,K)
   27 CONTINUE
      CALL ARRAY(2,NN,NB,NNDIM,NBDIM,BT,BT)
      NBT = NB
   25 CALL ARRAY(2,NN,NK,NNDIM,NKDIM,X,X)
      CALL CTIE(BT,X,A,NN,NBT,0,0,NK)
      NM=NBT+NK
      CALL ARRAY(1,NN,NM,NNDIM,NADIM,A,A)
      NBMOD=NB
      NTMOD=NT
      IF (NB.EQ.1) NBMOD=NB-1
      IF (NT.EQ.1) NTMOD=NT-1
C
C   NM EQUALS THE NUMEER OF COLUMNS IN THE DESIGN MATRIX
C
C   WRITE THE MATRIX FORM OF Y AND A FOR THE MAC MODEL
C
   26 WRITE(6,12)
   12 FORMAT(1H1,'THE VALUES OF Y AND A FOLLOW      MAC MODEL',///)
      IF (IPRKOD(1).EQ.0) GO TO 9797
      DO 13 I=1,NN
      WRITE(6,19) (Y(I,J),J=1,NP),(A(I,J),J=1,NM)
   19 FORMAT('0',14F9.2)
   13 CONTINUE
      GO TO 9795
 9797 WRITE(6,9796)
 9796 FORMAT('0','   THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(1)=0')
C
C   COMPUTE THE VARIATE FORM OF Y AND A FOR THE GMAC MODEL
C
 9795 DO 8 J=1,NP
C
C   WRITE THE VARIATE-WISE FORM OF Y AND A FOR GMAC MODEL
C
      WRITE(6,16) J
   16 FORMAT(1H1,'THE VALUES OF Y AND A FOR VARIATE',I2,'  FOLLOW
     *GMAC MODEL',///)
      IF (IPRKOD(2).EQ.0) GO TO 9794
      GO TO 9792
 9794 WRITE(6,9793)
 9793 FORMAT('0','   THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(2)=0')
 9792 ICT=0
      DO 9 I=1,NN
      IF(Y(I,J).EQ.D) GO TO 9
      ICT=ICT+1
      Z(ICT) = Y(I,J)
```

```
            DO 10 K=1,NM
            F(ICT,K) = A(I,K)
         10 CONTINUE
            IF (IPRKOD(2).EQ.0) GO TO 9
            WRITE(6,18) Z(ICT), (F(ICT,K),K=1,NM)
         18 FORMAT('0',14F9.2)
          9 CONTINUE
      C
      C     NCT(J) EQUAL THE NUMBER OF OBSERVATIONS FOR VARIATE J,J=1,....,NP
      C
            NCT(J)=ICT
            NBB=0
            IF(NMISS.EQ.0) GO TO 6000
            DO 3000 I = 1,NN
            DO 3000 K = 1,NMISS
            BB(I,K) = 0.0D0
       3000 CONTINUE
      C
      C     REMOVE MISSING VALUES FROM A MATRICES AND REPLACE BY ZEROES
      C     BUILD EXTRA COLUMSS FOR A MATRICES TO ACCOUNT FOR MISSING VALUES
      C
            KK=NBT+1
            DO 90 K=KK,NM
            L=NCT(J)
            NCM(J,K)=0
            DO 100 I = 1,L
            IF(F(I,K).NE.0) GO TO 100
            F(I,K) = 0.0D0
            NCM(J,K) = NCM(J,K) + 1
        110 KKK= NCM(J,K)
            BB(I,KKK) = 1.0D0
            NBB = NBB + 1
        100 CONTINUE
         90 CONTINUE
      C
      C     BUILD NEW A MATRICES FOR MGMAC MODEL BY AUGMENTATION
      C
            L = NCT(J)
      C
      C     NMA(J) EQUALS THE NUMBER OF COLUMNS IN THE DESIGN MATRIX FOR VARIATE J
      C
            NMA(J) = NM + NBB
            DO 130 K1=1,L
            NMP1 = NM + 1
            NMAJ = NMA(J)
            DO 130 K2 = NMP1,NMAJ
            NDUM = K2 - NMP1 + 1
            F(K1,K2) = BB(K1,NDUM)
        130 CONTINUE
      C
      C     WRITE THE VARIATE-WISE FORM OF Y AND A FOR THE MGMAC MODEL
      C
            WRITE(6,51) J
         51 FORMAT(1H1,'THE VALUES OF Y AND A FOR VARIATE',I2,' FOLLOW
           *MGMAC MODEL',///)
            IF (IPRKOD(3).EQ.0) GO TO 9791
            GO TO 9790
       9791 WRITE(6,9789)
```

```
 9789 FORMAT('0','    THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(3)=0')
      GO TO 6000
 9790 LL=NMA(J)
      DO 52 I=1,L
      WRITE(6,53) Z(I), (F(I,K),K=1,LL)
   53 FORMAT('0',14F9.2)
   52 CONTINUE
 6000 NMA(J) = NM + NEE
      L1=NCT(J)
      M1=NMA(J)
C
C   COMPUTE VARIANCE
C
C   FIND F'F
C
C   TEST FOR RANK OF F AND COMPUTE (F'F) INVERSE=RINV
C
      DO 3002 I = 1,M1
      DO 3002 L = 1,M1
      RSS(I,L) = 0.0DC
      DO 3003 K = 1,L1
      IF(F(K,I).EQ.0.CD0 00.OR.F(K,L).EQ.0.0D0 00) GO TO 3003
      RSS(I,L) = RSS(I,L) + F(K,I)*F(K,L)
 3003 CONTINUE
 3002 CONTINUE
      DO 900 I=1,M1
      DO 900 K=1,M1
      IK1=(I-1)*M1 + K
  900 RSSS(IK1)=RSS(I,K)
      CALL DMFGR(RSSS,M1,M1,EPS,IRANK,IROW,ICOL)
      IR(J) = IRANK
      WRITE(6,55) J,IR(J)
   55 FORMAT(1H0,'THE RANK OF THE DESIGN MATRIX FOR VARIATE',I5,' FOR TH
     *E MGMAC MODEL IS',I5,'    ',///)
      CALL LPSDOR(RSS,M1,M1,NFDIM,RSS,IDGT,T,IER)
      WRITE(6,9864) IER
 9864 FORMAT('0',/,' ','ERROR CODE FROM LPSDOR = ',I6,/)
C
C   FORM THE PRODUCT F(RINV)
C
 9753 DO 3004 I = 1,L1
      DO 3004 L = 1,M1
      S(I,L) = 0.0D0
      DO 3005 K = 1,M1
      IF(F(I,K).EQ.0.CD0 00.OR.RSS(K,L).EQ.0.0D0 00) GO TO 3005
      S(I,L) = S(I,L) + F(I,K)*RSS(K,L)
 3005 CONTINUE
 3004 CONTINUE
C
C
C   COMPUTE F(RINV)F'
C
      DO 3006 I = 1,L1
      DO 3006 L = 1,L1
      U(I,L) = 0.0D0
      DO 3007 K = 1,M1
      IF(S(I,K).EQ.0.CD0 00.OR.F(L,K).EQ.0.0D0 00) GO TO 3007
      U(I,L) = U(I,L) + S(I,K)*F(L,K)
```

```
0249          3007 CONTINUE
0250          3006 CONTINUE
             C
             C    COMPUTE  Z'IZ = Z'Z
             C
0251               ZZ(J) = 0.0D0
0252               DO 320 II=1,L1
0253               ZZ(J) = ZZ(J) + Z(II)**2
0254           320 CONTINUE
             C
             C    COMPUTE Z'F(RINV)F'
             C
0255               DO 3008 I = 1,L1
0256               V(I) = 0.0D0
0257               DO 3009 L = 1,L1
0258               IF(U(L,I).EQ.0.CD0 00) GO TO 3009
0259               V(I) = V(I) + Z(L)*U(L,I)
0260          3009 CONTINUE
0261          3008 CONTINUE
             C
             C    COMPUTE Z'F(RINV)F'Z
             C
0262               W = 0.0D0
0263               DO 3010 I = 1,L1
0264               W = W + Z(I)*V(I)
0265          3010 CONTINUE
0266               SIG(J,J) = (ZZ(J) - W)/(L1 - IR(J))
             C
             C    COMPUTE COVARIANCE
             C
0267               JJ = J + 1
0268               IF(JJ.GT.NP) GO TO 8
0269               DO 411 JJJ = JJ,NP
0270               ICTC = 0
0271               DO 409 I = 1,NN
0272               IF(Y(I,JJJ).EQ.D.OR.Y(I,J).EQ.D) GO TO 409
0273               ICTC = ICTC + 1
0274               Z(ICTC) = Y(I,J)
0275               ZY(ICTC) = Y(I,JJJ)
0276               DO 410 K = 1,NM
0277               F(ICTC,K) = A(I,K)
0278           410 CONTINUE
0279           409 CONTINUE
0280               NCTC(J,JJJ) = ICTC
0281               NBBC = 0
0282               IF(NMISS.EQ.0) GO TO 6001
0283               DO 3001 I = 1,NN
0284               DO 3001 K = 1,NMISS
0285               BB(I,K) = 0.0D0
0286          3001 CONTINUE
0287               KK = NBT + 1
0288               DO 490 K = KK,NM
0289               L = NCTC(J,JJJ)
0290               NCMC(J,JJJ,K) = 0
0291               DO 4100 I = 1,L
0292               IF(F(I,K).NE.D) GO TO 4100
0293               F(I,K) = 0.0D0
0294               NCMC(J,JJJ,K) = NCMC(J,JJJ,K) + 1
```

```
            KKK = NCMC(J,JJJ,K)
            BB(I,KKK) = 1.0D0
            NBBC = NBBC + 1
      4100  CONTINUE
       490  CONTINUE
            L = NCTC(J,JJJ)
            NMAC(J,JJJ) = NM + NBBC
            DO 4130 K1 = 1,L
            NMP1 = NM + 1
            NMAJ = NMAC(J,JJJ)
            DO 4130 K2 = NMP1,NMAJ
            NDUM = K2 - NMP1 + 1
            F(K1,K2) = BB(K1,NDUM)
      4130  CONTINUE
      6001  NMAC(J,JJJ) = NM + NBBC
            L2 = NCTC(J,JJJ)
            M2 = NMAC(J,JJJ)
C
C     FIND F'F
C
            DO 3012 I = 1,M2
            DO 3012 L = 1,M2
            RSS(I,L) = 0.0D0
            DO 3013 K = 1,L2
            IF(F(K,I).EQ.0.0D0 00.OR.F(K,L).EQ.0.0D0 00) GO TO 3013
            RSS(I,L) = RSS(I,L) + F(K,I)*F(K,L)
      3013  CONTINUE
      3012  CONTINUE
C
C     TEST FOR RANK OF F AND COMPUTE INVERSE
C
            DO 901 I = 1,M2
            DO 901 K = 1,M2
            IK1=(I-1)*M2 + K
            RSSS(IK1)=RSS(I,K)
       901  CONTINUE
            CALL DMFGR(RSSS,M2,M2,EPS,IRANK,IROW,ICOL)
            IRR(J,JJJ) = IRANK
            CALL LPSDOR(RSS,M2,M2,NFDIM,RSS,IDGT,T,IER)
            WRITE(6,9864) IER
C
C     FORM THE PRODUCT F(RINV)
C
            DO 3014 I = 1,L2
            DO 3014 L = 1,M2
            S(I,L) = 0.0D0
            DO 3015 K = 1,M2
            IF(F(I,K).EQ.0.0D0 00.OR.RSS(K,L).EQ.0.0D0 00) GO TO 3015
            S(I,L) = S(I,L) + F(I,K)*RSS(K,L)
      3015  CONTINUE
      3014  CONTINUE
C
C     COMPUTE F(RINV)F'
C
            DO 3016 I = 1,L2
            DO 3016 L = 1,L2
            U(I,L) = 0.0D0
            DO 3017 K = 1,M2
```

```
           IF(S(I,K).EQ.0.0D0 00.OR.F(L,K).EQ.0.0D0 00) GO TO 3017
           U(I,L) = U(I,L) + S(I,K)*F(L,K)
      3017 CONTINUE
      3016 CONTINUE
C
C    COMPUTE Z'IZZ
C
           ZZ(J) = 0.0D0
           DO 620 II= 1,L2
           ZZ(J) = ZZ(J) + Z(II)*ZY(II)
       620 CONTINUE
C
C    COMPUTE  Z'F(RINV)F'
C
           DO 3018 I = 1,L2
           V(I) = 0.0D0
           DO 3019 L = 1,L2
           IF(U(L,I).EQ.0.CD0 00) GO TO 3019
           V(I) = V(I) + Z(L)*U(L,I)
      3019 CONTINUE
      3018 CONTINUE
C
C.   COMPUTE Z'F(RINV)F'ZY
           W = 0.0D0
           DO 3020 I = 1,L2
           W = W + ZY(I)*V(I)
      3020 CONTINUE
           SIG(J,JJJ) = (ZZ(J) - W)/(L2 - IRR(J,JJJ))
           SIG(JJJ,J) = SIG(J,JJJ)
       411 CONTINUE
         8 CONTINUE
C
C *** CALL TO SMOOTH FOLLOWS THIS CARD
C
           CALL SMOOTH(SIG,NP,1)
C
C    WRITE OUT SIGMA AND SIGMA INVERSE
C
           WRITE(6,695)
       695 FORMAT(1H1,'THE VALUE OF SIGMA FOLLOWS',///)
           IF (IPRKOD(4).EQ.0) GO TO 9786
           DO 9788 JJJ=1,NF
     -     WRITE(6,9787) (SIG(JJJ,JJJJ),JJJJ=1,NP)
      9787 FORMAT('0',10(1X,G12.6))
      9788 CONTINUE
           GO TO 9784
      9786 WRITE(6,9785)
      9785 FORMAT('0','     THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(4)=0')
      9784 CALL LPSDOR(SIG,NP,NP,NPDIM,SIGINV,IDGT,T,IER)
           WRITE(6,9864) IER
           WRITE(6,699)
       699 FORMAT(1H1,'THE VALUE OF SIGMA INVERSE FOLLOWS',///)
           IF (IPRKOD(4).EQ.0) GO TO 9783
           DO 9782 JJJ=1,NF
           WRITE(6,9781) (SIGINV(JJJ,JJJJ),JJJJ=1,NP)
      9781 FORMAT('0',10(1X,G12.6))
      9782 CONTINUE
           GO TO 9780
```

```
      9783 WRITE(6,9785)
C
C      REMOVE MISSING VALUES FROM A AND REPLACE BY ZEROES
C      BUILD EXTRA COLUMNS FOR A MATRIX TO ACCOUNT FOR MISSING VALUES
C
      9780 NBB = 0
           IF(NMISS.EQ.0) GO TO 6002
           DO 5005 I = 1,NN
           DO 5005 K = 1,NMISS
           BB(I,K) = 0.0D0
      5005 CONTINUE
           KK = NBT + 1
           DO 1011 K = KK,NM
           NCMK(K) = 0
           DO 1012 I = 1,NN
           IF(A(I,K).NE.D) GO TO 1012
           A(I,K) = 0.0D0
           NCMK(K) = NCMK(K) + 1
           KKK = NCMK(K)
           BB(I,KKK) = 1.0D0
           NBB = NBB + 1
      1012 CONTINUE
      1011 CONTINUE
C
C      BUILD NEW A MATRIX FOR MATRIX MODIFIED MODEL
C
C      NA EQUALS THE NUMBER OF COLUMNS IN THE MODIFIED DESIGN MATRIX
C
           NA = NM + NBB
           DO 1114 K1 = 1,NN
           NMP1 = NM + 1
           DO 1114 K2 = NMP1,NA
           NDUM = K2 - NMP1 + 1
           A(K1,K2) = BB(K1,NDUM)
      1114 CONTINUE
C
C      WRITE THE MATRIX MODIFIED FORM OF Y AND A
C
           WRITE(6,1020)
      1020 FORMAT(1H1,'THE VALUES OF Y AND A FOLLOW
          *MATRIX MODIFIED MODEL',///)
           IF (IPRKOD(5).EQ.0) GO TO 9779
           DO 1021 I = 1,NN
           WRITE(6,1022) (Y(I,J),J=1,NP),(A(I,K),K=1,NA)
      1022 FORMAT('0',14F9.2)
      1021 CONTINUE
           WRITE(6,9729)
      9729 FORMAT('1','          ****** DEPENDENT VARIABLES AND DESIGN MATRIX FOR
          % THE VARIOUS GROUPS CORRESPONDING TO DIFFERENT PATTERNS OF MISSING
          $ VALUES')
           NDIGRP=2**NP - 1
           WRITE(6,9703) NDIGRP,NDIGRP
      9703 FORMAT('0','**** THERE ARE ',I4,' DIFFERENT POSSIBLE GROUPS NUMBER
          XED FROM 1 TO',I4,' THOUGH IN GENERAL NOT ALL GROUPS WILL APPEAR',/
          @/,'0','*** WHICH ONES OCCUR DEPENDS ON THE PATTERN OF MISSING VALU
          <ES.HOWEVER THE TOTAL # OBSERVATIONS IN ALL GROUPS MUST EQUAL NN')
           GO TO 6002
      9779 WRITE(6,9778)
```

```
 9778 FORMAT('0','     THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(5)=0')
      WRITE(6,9729)
 6002 NA = NM + NBB
      DO 1019 J = 1,NP
      B(J,J) = 1.000
 1019 CONTINUE
      DO 1000 I = 1,NN
      IND(I) = 0
      DO 1001 J = 1,NP
      IF(Y(I,J).NE.D) GC TO 1030
      IN(I,J) = 0
 1030 L = NP - J
      IND(I) = IND(I) + IN(I,J)*2**L
 1001 CONTINUE
 1000 CONTINUE
      KP = 2**NP - 1
      DO 1002 LL = 1,KP
      NCL(LL) = 0
      DO 1003 I = 1,NN
      IF(IND(I).NE.LL) GO TO 1003
      NCL(LL) = NCL(LL) + 1
      ICT = NCL(LL)
      DO 1004 J = 1,NP
      YS(ICT,J) = Y(I,J)
 1004 CONTINUE
      DO 1005 K = 1,NA
      AS(ICT,K) = A(I,K)
 1005 CONTINUE
 1003 CONTINUE
      IF(NCL(LL).EQ.0) GO TO 1002
      JCT = 0
      DO 1007 J = 1,NF
      IF(YS(1,J) .EQ.C) GO TO 1007
      JCT = JCT + 1
      DO 1008 JJ = 1,NP
      BS(JJ,JCT) = B(JJ,J)
 1008 CONTINUE
 1007 CONTINUE
      NCJ(LL) = JCT
C
C     WRITE THE GROUPED CATA FORM OF Y AND A FOR THE MODIFIED MATRIX MODEL
C
      K = NCL(LL)
      JJ = NCJ(LL)
      WRITE(6,1032) LL,K,JJ
 1032 FORMAT(1H0,'THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRI
     *X FOLLOW FOR GRCUP',I5,' WHICH HAS',I5,' OBSERVATIONS ON',I5,' VAR
     *IATES',///)
      IF (IPRKOD(6).EQ.0) GO TO 9777
      DO 1024 I = 1,K
      WRITE(6,1025) (YS(I,J),J=1,NP),(AS(I,KK),KK=1,NA)
 1025 FORMAT('0',14F9.2)
 1024 CONTINUE
      GO TO 9776
 9777 WRITE(6,9775)
 9775 FORMAT('0','     THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(6)=0')
C
C     COMPUTE THE SUM OVER ALL GROUPS OF (B(INV(B'*SIGMA*B))XA')Y
```

```
C
C     COMPUTE     B'*SIGMA
C
 9776 NAP = NA*NP
      NJ = NCJ(LL)
      DO 1036 I = 1,NJ
      DO 1036 L = 1,NF
      BSIG(I,L) = 0.0D0
      DO 2066 K = 1,NF
      IF(BS(K,I).EQ.0.0D0 00) GO TO 2066
      BSIG(I,L) = BSIG(I,L) + BS(K,I)*SIG(K,L)
 2066 CONTINUE
 1036 CONTINUE
C
C     COMPUTE     B'*SIGMA*B
C
      DO 1037 I = 1,NJ
      DO 1037 L = 1,NJ
      BSIGB(I,L) = 0.CD0
      DO 2067 K = 1,NF
      IF(BS(K,L).EQ.0.0D0 00) GO TO 2067
      BSIGB(I,L) = BSIGB(I,L) + BSIG(I,K)*BS(K,L)
 2067 CONTINUE
 1037 CONTINUE
C
C     COMPUTE          INV(B'*SIGMA*B)
C
      IF(NJ.EQ.1) GO TO 1038
      CALL LPSDOR(BSIGB,NJ,NJ,NPDIM,BSIGB,IDGT,T,IER)
      WRITE(6,9864) IER
      GO TO 1039
 1038 BSIGB(NJ,NJ) = 1.0D0/BSIGB(NJ,NJ)
C
C     COMPUTE          B(INV(B'*SIGMA*B))
C
 1039 DO 1040 I = 1,NF
      DO 1040 L = 1,NJ
      BBSIGI(I,L) = 0.0D0
      DO 2070 K = 1,NJ
      IF(BS(I,K).EQ.0.0D0 00) GO TO 2070
      BBSIGI(I,L) = BBSIGI(I,L) + BS(I,K)*BSIGB(K,L)
 2070 CONTINUE
 1040 CONTINUE
C
C     COMPUTE          (B(INV(B'*SIGMA*B))XA')
C
      NL = NCL(LL)
C
C     GET COLUMNS OF Y
C
      DO 1042 I = 1,NL
      DO 1042 J = 1,NJ
      YYS(I,J) = 0.0DC
      DO 2072 K = 1,NF
      IF(BS(K,J).EQ.0.0D0 00) GO TO 2072
      YYS(I,J) = YYS(I,J) + YS(I,K)*BS(K,J)
 2072 CONTINUE
 1042 CONTINUE
```

```
C
C    COMPUTE      B(INV(B'*SIGMA*B))XA')Y
C
         II = 0
         DO 1043 I = 1,NP
         DO 1043 K = 1,NA
         II = II + 1
         DO 1043 J = 1,NJ
         DO 2073 L = 1,NL
         IF(BBSIGI(I,J).EQ.0.0D0 00.OR.AS(L,K).EQ.0.0D0 00) GO TO 2073
         RV(II) = RV(II) + BBSIGI(I,J)*AS(L,K)*YYS(L,J)
  2073 CONTINUE
  1043 CONTINUE
C
C     COMPUTE THE SUM CVER ALL GROUPS OF  ((B(INV(B'*SIGMA*B)B')XA'A)
C    AND COMPUTE THE INVERSE
C
C    COMPUTE      B(INV(B'*SIGMA*B)B'
C
         DO 1051 I = 1,NP
         DO 1051 L = 1,NP
         BSIGIB(I,L) = 0.0D0
         DO 2081 K = 1,NJ
         IF(BS(L,K).EQ.0.0D0 00.OR.BBSIGI(I,K).EQ.0.0D0 00) GO TO 2081
         BSIGIB(I,L) = BSIGIB(I,L) + BBSIGI(I,K)*BS(L,K)
  2081 CONTINUE
  1051 CONTINUE
C
C    COMPUTE      A'A
C
         NL = NCL(LL)
         DO 1052 I = 1,NA
         DO 1052 L = 1,NA
         AJA(I,L) = 0.0D0
         DO 2082 K = 1,NL
         IF(AS(K,I).EQ.0.0C0 00) GO TO 2082
         AJA(I,L) = AJA(I,L) + AS(K,I)*AS(K,L)
  2082 CONTINUE
  1052 CONTINUE
C
C    COMPUTE      (B(INV(B'*SIGMA*B)B')XA'A
C
C    PUT THE ABOVE INTC A MATRIX
C
         II = 0
         DO 1054 I = 1,NP
         DO 1054 K = 1,NA
         KK = 0
         II = II + 1
         DO 1054 J = 1,NP
         DO 1054 L = 1,NA
         KK = KK + 1
         PROD2(II,KK) = FRCD2(II,KK) + BSIGIB(I,J)*AJA(L,K)
  1054 CONTINUE
  1002 CONTINUE
C
C    COMPUTE THE INVERSE OF THE ABOVE SUM
C
```

```
0554                CALL LPSDOR(PROD2,NAP,NAP,NPRCD,PROD2,IDGT,T,IER)
0555                WRITE(6,9864) IER
0556                DO 1056 I = 1,NAP
0557                BETA(I) = 0.0D0
              C
              C   COMPUTE BETA ESTIMATES
              C
0558                DO 1056 L = 1,NAP
0559                BETA(I) = BETA(I) + PROD2(I,L)*RV(L)
0560           1056 CONTINUE
0561                DO 9728 I8=1,NP
0562                DO 9728 I9=1,NA
0563                I7=(I8-1)*NA+I9
0564           9728 BETAMX(I9,I8)=BETA(I7)
0565                WRITE(6,1067)
0566           1067 FORMAT('1','         ****** LISTING OF PARAMETER ESTIMATES IN THE ORD
                   #ER : BLOCKS, TRTS, REGRESSION COEFFICIENTS DOWN THE PAGE ******')
0567                IF (IPRKOD(7).EQ.0) GO TO 9774
0568                WRITE(6,1062)
0569           1062 FORMAT('0','             VAR#1                 VAR#2                 VAR#3
                   <             VAR#4                 VAR#5                 VAR#6
                   %  VAR#7')
0570                DO 1060 I8=1,NM
0571                WRITE(6,9727) (BETAMX(I8,I9),I9=1,NP)
0572           9727 FORMAT('0',7(1X,G18.6))
0573           1060 CONTINUE
              C     WRITE(6,1926)
              C1926 FORMAT(//,' ','                  ****** ESTIMATES OF DUMMY PARAMETERS INT
              C    %RODUCED BECAUSE OF MISSING VALUES ******')
              C     IF (NM.EQ.NA) GO TO 1919
              C     NMP1=NM+1
              C     DO 1925 I8=NMP1,NA
              C     WRITE(6,9727) (BETAMX(I8,I9),I9=1,NP)
              C1925 CONTINUE
              C     GO TO 1917
              C1919 WRITE(6,1918)
              C1918 FORMAT('0','                        THERE ARE NO DUMMY PARAMETERS ( THERE WER
              C    #E NO MISSING VALUES )')
0574                GO TO 1917
0575           9774 WRITE(6,9773)
0576           9773 FORMAT('0','    THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(7)=0')
0577           1917 CONTINUE
              C
              C   READ IN THE SPECIFIED HYPOTHESES MATRICES
              C
0578                WRITE(6,9756)
0579           9756 FORMAT('1','                               ****** HYPOTHESIS TESTING SEC
                   $TION ****** ',///)
0580                READ(5,2020) NUMHYP
0581           2020 FORMAT(I5)
0582                WRITE(6,9772) NUMHYP
0583           9772 FORMAT('0',I5,' HYPOTHESIS MATRICES SHALL BE USED,IN TURN,FOR COMP
                   #UTING CHI SQUARE STATISTICS',///)
0584                WRITE(6,9771) NM
0585           9771 FORMAT('0','EACH MATRIX SHOULD HAVE ',I5,' COLUMNS AS FOLLOWS : ')
0586                WRITE(6,9759) NEWCD
0587           9759 FORMAT('0',' THE FIRST ',I5,' COLUMNS CORRESPOND TO BLOCK PARAMETE
                   %RS')
```

```
      WRITE(6,9758) NTMOD
 9758 FORMAT(' ',' THE NEXT  ',I5,' COLUMNS CORRESPOND TO TREATMENT PARA
     %METERS')
      WRITE(6,9757) NK
 9757 FORMAT(' ',' THE LAST  ',I5,' COLUMNS CORRESPOND TO COVARIATE COEF
     %FICIENTS')
      DO 2000 I = 1,NUMHYP
      READ(5,2021) NUMROW(I),HYPID,KODOVL,(KDRESP(I9),I9=1,NP)
 2021 FORMAT(I5,5A4,20I2)
      NR = NUMROW(I)
      WRITE(6,1999) I,HYPID
 1999 FORMAT(1H1,'**** LISTING OF HYPOTHESIS MATRIX',I5,' FOLLOWED BY IT
     @S EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: ',5A4,///)
      DO 2001 J = 1,NR
      READ(5,2022) (H(J,K),K=1,NM)
 2022 FORMAT(20F4.2)
      WRITE(6,1998) (H(J,K),K=1,NM)
 1998 FORMAT('0',20(1X,F5.2))
 2001 CONTINUE
      NRP = NR*NP
C
C               NRP=NR*NP AND NAP=NA*NP
C.
C   EXTEND HYPOTHESIS MATRIX TO ACCOUNT FOR ADDITIONAL PARAMETERS
C   RESULTING FROM MISSING INDEPENDENT VARIABLES
C
      IF(NM.EQ.NA) GO TO 2002
      DO 2003 J = 1,NR
      DO 2003 K = 1,NEB
      KK = NM + K
      H(J,KK) = 0.0D0
 2003 CONTINUE
C
C   BUILD HYPOTHESIS MATRIX FOR PARAMETER VECTOR
C
 2002 DO 2004 L = 1,NP
      DO 2004 J = 1,NR
      JJ = J + NR*(L - 1)
      DO 2004 K = 1,NA
      KK = K + NA*(L - 1)
      H(JJ,KK) = H(J,K)
 2004 CONTINUE
      DO 4000 J=1,NRP
      WRITE(6,9755) J,(H(J,K),K=1,NAP)
 9755 FORMAT(' ',//,' ','ROW(',I2,'): ',20(1X,F5.2))
 4000 CONTINUE
      IF (KODOVL.EQ.0) GO TO 9749
C
C   COMPUTE THE TEST STATISTIC
C
C   COMPUTE H'*PRINV
C
      DO 2005 J = 1,NRP
      DO 2005 L = 1,NAP
      HPRNV(J,L) = 0.0D0
      DO 2006 K = 1,NAP
      IF(H(J,K).EQ.0.0D0 00.OR.PROD2(K,L).EQ.0.0D0 00) GO TO 2006
      HPRNV(J,L) = HPRNV(J,L) + H(J,K)*PROD2(K,L)
```

```
      2006 CONTINUE
      2005 CONTINUE
C
C     COMPUTE H'*PRINV*H
C
           DO 2007 J = 1,NFP
           DO 2007 L = 1,NFP
           HPRH(J,L) = 0.0D0
           DO 2008 K = 1,NAP
           IF(HPRNV(J,K).EQ.0.0D0 00.OR.H(L,K).EQ.0.0D0 00) GO TO 2008
           HPRH(J,L) = HPRH(J,L) + HPRNV(J,K)*H(L,K)
      2008 CONTINUE
      2007 CONTINUE
C
C     COMPUTE THE INVERSE OF H'*PRINV*H
C
           CALL LPSDOR(HPRH,NFP,NFP,NHPRHD,HPRH,IDGT,T,IER)
           WRITE(6,9864) IER
C
C     COMPUTE H'*BETA
C
           DO 2009 J = 1,NFP
           HBETA(J) = 0.0D0
           DO 2010 L = 1,NAP
           IF(H(J,L).EQ.0.0D0 00) GO TO 2010
           HBETA(J) = HBETA(J) + H(J,L)*BETA(L)
      2010 CONTINUE
      2009 CONTINUE
C
C     COMPUTE (H'*BETA)'(INV(H'*PRINV*H))
C
           DO 2011 J = 1,NFP
           HBETAP(J) = 0.0D0
           DO 2011 L = 1,NFP
           HBETAP(J) = HBETAP(J) + HBETA(L)*HPRH(J,L)
      2011 CONTINUE
C
C     COMPUTE (H*BETA)'(INV'H'*PRINV*H))(H*BETA)
C
           WALD = 0.0D0
           DO 2012 J = 1,NFP
           WALD = WALD + HBETAP(J)*HBETA(J)
      2012 CONTINUE
           WRITE(6,2013) I,NF,WALD
      2013 FORMAT(1H0,//,1H0,'THE WALD STATISTIC FOR HYPOTHESIS',I4,' FOR ALL
          # ',I4,' RESPONSE VARIABLES SIMULTANEOUSLY IS : ',F15.4,//)
           WRITE(6,2015) NFF
      2015 FORMAT('0','ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS
          # IS CHI-SQUARE WITH ',I4,' DEGREES OF FREEDOM',///)
C
C   COMPUTE THE TEST STATISTIC FOR THE TESTS ON INDIVIDUAL RESPONSE VARIABLES
C
      9749 WRITE(6,9750) I,HYPID
      9750 FORMAT('1',' ****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARI
          @ATES FOR HYPOTH MATRIX',I3,' WITH ID: ',5A4,' ******',///)
           WRITE(6,9708) NP,(KORESP(I9),I9=1,NP)
      9708 FORMAT(//,' ',' *** THE OPTIONS FOR THE ',I3,' INDIVIDUAL VARIATE
          %S ARE: ',10I3,/)
```

```
            DO 9748 IV=1,NP
            IF (KDRESP(IV).EQ.0) GO TO 9748
      C
      C   EXTRACT APPROPRIATE PART OF  THE H MATRIX CONSTRUCTED EARLIER
      C
            DO 9747 IV1=1,NR
            DO 9747 IV2=1,NAP
            IV3=(IV-1)*NR+IV1
       9747 HP(IV1,IV2)=H(IV3,IV2)
      C
      C   COMPUTE H'*PRINV
      C
            DO 9746 J=1,NR
            DO 9746 L=1,NAP
            HPRNV(J,L)=0.D0
            DO 9745 K=1,NAP
            IF (HP(J,K).EQ.0.D0.OR.PROD2(K,L).EQ.0.D0) GO TO 9745
            HPRNV(J,L)=HPRNV(J,L) + HP(J,K)*PROD2(K,L)
       9745 CONTINUE
       9746 CONTINUE
      C
      C   COMPUTE H'*PRINV*H
      C
            DO 9744 J=1,NR
            DO 9744 L=1,NR
            HPRH(J,L)=0.D0
            DO 9743 K=1,NAP
            IF (HPRNV(J,K).EQ.0.D0.OR.HP(L,K).EQ.0.D0) GO TO 9743
            HPRH(J,L)=HPRH(J,L) + HPRNV(J,K)*HP(L,K)
       9743 CONTINUE
       9744 CONTINUE
      C
      C   COMPUTE THE INVERSE OF H'*PRINV*H
      C
            CALL LPSDOR(HPRH,NR,NR,NHPRHD,HPRH,IDGT,T,IER)
            WRITE(6,9864) IER
      C
      C   COMPUTE H'*BETA
      C
            DO 9742 J=1,NR
            HBETA(J)=0.D0
            DO 9741 L=1,NAP
            IF (HP(J,L).EQ.0.D0) GO TO 9741
            HBETA(J)=HBETA(J) + HP(J,L)*BETA(L)
       9741 CONTINUE
       9742 CONTINUE
      C
      C   COMPUTE (H'*BETA)'(INV(H'*PRINV*H))
      C
            DO 9740 J=1,NR
            HBETAP(J)=0.D0
            DO 9740 L=1,NR
            HBETAP(J)=HBETAP(J) + HBETA(L)*HPRH(J,L)
       9740 CONTINUE
      C
      C   COMPUTE (H*BETA)'(INV'H'*PRINV*H))(H*BETA)
      C
            WALD=0.D0
```

```
      DO 9739 J=1,NR
 9739 WALD=WALD + HBETAF(J)*HBETA(J)
      WRITE(6,9738) I,IV,WALD
 9738 FORMAT('0','THE WALD STATISTIC FOR HYPOTHESIS ',I4,' RESTRICTED TO
     % RESPONSE VARIATE ',I4,' ONLY IS : ',F15.4,/)
      WRITE(6,9737) NF
 9737 FORMAT('0','ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS
     # IS CHI-SQUARE WITH ',I4,' DEGREES OF FREEDOM',////)
 9748 CONTINUE
      DO 9736 I9=1,NHFRHD
      DO 9736 I8=1,NPFOD
 9736 H(I9,I8)=0.D0
 2000 CONTINUE
 9999 STOP
      DEBUG SUBCHK
      END
```

```
FORTRAN IV G1  RELEASE 2.0                MAIN                 DATE = 76320            21/26/16

  *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
  *OPTIONS IN EFFECT*  NAME = MAIN     , LINECNT =        60
  *STATISTICS*     SOURCE STATEMENTS =        715,PROGRAM SIZE =    376500
  *STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
FORTRAN IV G1   RELEASE 2.0 SMOOTH            DATE = 76320          21/26/16
          SUBROUTINE SMOOTH(AI,N,KOD)
    C
    C *** THIS SUBROUTINE ACCEPTS A DOUBLE PRECISION INPUT MATRIX AI OF DIMENSION
    C *** N BY N AND CHECKS TO SEE IF IT IS POSITIVE SEMIDEFINITE. IF SO IT IS LEFT
    C *** INTACT AND RETURNED. IF NOT IT IS SMOOTHED BY THE LEAST SQUARES ALGORITHM
    C *** ( NOT GENERALIZED LEAST SQUARES ) OF SCHWERTMAN AND ALLEN (UNIV KENTUCKY
    C *** DEPT. STATISTICS TECH REPORT #56,SEPTEMBER 1973) TO THE NEAREST POSITIVE
    C *** SEMIDEFINITE MATRIX AND RETURNED.
    C ***
    C *** AN OPTION IS AVAILABLE TO PRINT BOTH THE MATRIX SUBMITTED TO THE ROUTINE
    C *** AND THE ONE RETURNED BY IT :
    C ***                   KCC = 0 BYPASSES THE PRINT OPTION
    C ***                   KCD = 1 INVOKES THE PRINT OPTION.
    C ***
    C ***
    C *** THE PROGRAM CAN BE MADE TO HANDLE LARGER MATRICES BY INCREASING NDIM, THE
    C *** DIMENSIONS OF VA, EG, AND AI IN THE SUBROUTINE SMOOTH. THESE SHOULD MATCH
    C *** THE DIMENSION OF THE AREA HOLDING THE INPUT MATRIX IN THE CALLING PROGRAM.
    C
          REAL*8 VA(7,7),TRC,EG(7,7),AI(7,7)
          NDIM=7
          DO 14 I=1,N
          DO 14 J=1,N
       14 VA(I,J)=AI(I,J)
          IF (KOD.EQ.0) GC TO 13
          CALL MATOUT (VA,N,N,'INPUT MATRIX TO SMOOTH  ',NDIM,NDIM)
       13 TRC=0.0D0
          CALL HDIAG(VA,N,C,EG,NR,NDIM)
          DO 15 I=1,N
          IF (VA(I,I).LT.C.0DO) TRC=TRC+VA(I,I)
       15 CONTINUE
          DO 16 I=1,N
          IF (VA(I,I).LT.C.0DO) GO TO 17
       16 CONTINUE
          GO TO 40
       17 DO 21 I=1,N
          DO 21 J=1,N
       21 AI(I,J)=0.0DO
          DO 20 I=1,N
          IF (VA(I,I).LT.0.0DO) GO TO 20
          DO 19 J=1,N
          DO 19 L=1,N
          AI(J,L)=AI(J,L) + EG(J,I) * VA(I,I) * EG(L,I)
       19 CONTINUE
       20 CONTINUE
       40 IF (KOD.EQ.0) GC TO 41
          CALL MATOUT(AI,N,N,'MATRIX OUTPUT BY SMOOTH ',NDIM,NDIM)
       41 RETURN
          DEBUG SUBCHK
          END
```

```
FORTRAN IV G1  RELEASE 2.0              SMOOTH              DATE = 76320          21/26/16

   *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
   *OPTIONS IN EFFECT*  NAME = SMOOTH    , LINECNT =       60
   *STATISTICS*     SOURCE STATEMENTS =        32,PROGRAM SIZE =       2352
   *STATISTICS*  NO DIAGNOSTICS GENERATEC
```

```
FORTRAN IV G1  RELEASE 2.0            HDIAG                   DATE = 76320            21/26/16

 0001                SUBROUTINE HDIAG (H,N,IEGEN,U,NR,NN)
 0002                IMPLICIT REAL*8 (A-H,O-Z)
 0003                  DIMENSION H(NN,NN),U(NN,NN),X(100),IQ(100)
 0004                IF(IEGEN)50,10,50
 0005             10 DO40I=1,N
 0006                DO40J=1,N
 0007                IF(I-J)30,20,30
 0008             20 U(I,J)=1.0D0
 0009                GOTO40
 0010             30 U(I,J)=0.0D0
 0011             40 CONTINUE
 0012             50 NR=0
 0013                IF(N-1)470,470,60
 0014             60 NMI1=N-1
 0015                DO80I=1,NMI1
 0016                X(I)=0.0D0
 0017                IPL1=I+1
 0018                DO80J=IPL1,N
 0019                IF(X(I)-DABS(H(I,J)))70,70,80
 0020             70 X(I)=DABS(H(I,J))
 0021                IQ(I)=J
 0022             80 CONTINUE
 0023                RAP=7.450580596D-9
 0024                HDTEST=1.0D38
 0025             90 DO120I=1,NMI1
 0026                IF(I-1)110,110,100
 0027            100 IF(XMAX-X(I))110,120,120
 0028            110 XMAX=X(I)
 0029                IPIV=I
 0030                JPIV=IQ(I)
 0031            120 CONTINUE
 0032                IF(XMAX)470,470,130
 0033            130 IF(HDTEST)150,150,140
 0034            140 IF(XMAX-HDTEST)150,150,180
 0035            150 HDIMIN=DABS(H(1,1))
 0036                DO170I=2,N
 0037                IF(HDIMIN-DABS (H(I,I)))170,170,160
 0038            160 HDIMIN=DABS (H(I,I))
 0039            170 CONTINUE
 0040                HDTEST=HDIMIN*RAP
 0041                IF(HDTEST-XMAX)180,470,470
 0042            180 NR=NR+1
 0043                IF(H(IPIV,IPIV)-H(JPIV,JPIV))200,190,200
 0044            190 S=1.0D0
 0045                TANG=DSIGN (2.0D0,S)*H(IPIV,JPIV)/(DABS(H(IPIV,IPIV)-H(JPIV,JPIV))
                    1+DSQRT ((H(IPIV,IPIV)-H(JPIV,JPIV))**2+4.0D0*H(IPIV,JPIV)**2))
 0046                GO TO 210
 0047            200 TANG=DSIGN (2.0D0,(H(IPIV,IPIV)-H(JPIV,JPIV)))*H(IPIV,JPIV)/(DABS(
                    1H(IPIV,IPIV)-H(JPIV,JPIV))+DSQRT ((H(IPIV,IPIV)-H(JPIV,JPIV))**2+4
                    2.0D0*H(IPIV,JPIV)**2))
 0048            210 COSINE=1.0/DSQRT (1.0D0+TANG**2)
 0049                SINE=TANG*COSINE
 0050                HII=H(IPIV,IPIV)
 0051                H(IPIV,IPIV)=COSINE**2*(HII+TANG*(2.0D0*H(IPIV,JPIV)+TANG*H(JPIV,J
                    1PIV)))
 0052                H(JPIV,JPIV)=COSINE**2*(H(JPIV,JPIV)-TANG*(2.0D0*H(IPIV,JPIV)-TANG
                    1*HII))
 0053                H(IPIV,JPIV)=0.0D0
```

```
          IF(H(IPIV,IPIV)-H(JPIV,JPIV))220,230,230
      220 HTEMP=H(IPIV,IPIV)
          H(IPIV,IPIV)=H(JPIV,JPIV)
          H(JPIV,JPIV)=HTEMP
          HTEMP=DSIGN (1.0D0,-SINE)*COSINE
          COSINE=DABS (SINE)
          SINE=HTEMP
      230 CONTINUE
          DO310I=1,NMI1
          IF(I-IPIV)250,310,240
      240 IF(I-JPIV)250,310,250
      250 IF(IQ(I)-IPIV)260,270,260
      260 IF(IQ(I)-JPIV)310,270,310
      270 K=IQ(I)
      280 HTEMP=H(I,K)
          H(I,K)=0.0D0
          IPL1=I+1
          X(I)=0.0D0
          DO300J=IPL1,N
          IF(X(I)-DABS (H(I,J)))290,290,300
      290 X(I)=DABS (H(I,J))
          IQ(I)=J
      300 CONTINUE
          H(I,K)=HTEMP
      310 CONTINUE
          X(IPIV)=0.0D0
          X(JPIV)=0.0D0
          DO440I=1,N
          IF(I-IPIV)320,440,360
      320 HTEMP=H(I,IPIV)
          H(I,IPIV)=COSINE*HTEMP+SINE*H(I,JPIV)
          IF(X(I)-DABS (H(I,IPIV)))330,340,340
      330 X(I)=DABS (H(I,IPIV))
          IQ(I)=IPIV
      340 H(I,JPIV)=-SINE*HTEMP+COSINE*H(I,JPIV)
          IF(X(I)-DABS (H(I,JPIV)))350,440,440
      350 X(I)=DABS (H(I,JPIV))
          IQ(I)=JPIV
          GOTO440
      360 IF(I-JPIV)370,440,400
      370 HTEMP=H(IPIV,I)
          H(IPIV,I)=COSINE*HTEMP+SINE*H(I,JPIV)
          IF(X(IPIV)-DABS (H(IPIV,I)))380,390,390
      380 X(IPIV)=DABS(H(IPIV,I))
          IQ(IPIV)=I
      390 H(I,JPIV)=-SINE*HTEMP+COSINE*H(I,JPIV)
          IF(X(I)-DABS(H(I,JPIV)))350,440,440
      400 HTEMP=H(IPIV,I)
          H(IPIV,I)=COSINE*HTEMP+SINE*H(JPIV,I)
          IF(X(IPIV)-DABS (H(IPIV,I)))410,420,420
      410 X(IPIV)=DABS (H(IPIV,I))
          IQ(IPIV)=I
      420 H(JPIV,I)=-SINE*HTEMP+COSINE*H(JPIV,I)
          IF(X(JPIV)-DABS (H(JPIV,I)))430,440,440
      430 X(JPIV)=DABS (H(JPIV,I))
          IQ(JPIV)=I
      440 CONTINUE
          IF(IEGEN)90,450,90
```

```
  450 DO460I=1,N
      HTEMP=U(I,IPIV)
      U(I,IPIV)=COSINE*HTEMP+SINE*U(I,JPIV)
  460 U(I,JPIV)=-SINE*HTEMP+COSINE*U(I,JPIV)
      GOTO90
  470 RETURN
      DEBUG SUBCHK
      END
```

```
FORTRAN IV G1  RELEASE 2.0                HDIAG              DATE = 76320          21/26/16

  *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
  *OPTIONS IN EFFECT*  NAME = HDIAG    , LINECNT =        60
  *STATISTICS*    SOURCE STATEMENTS =      119,PROGRAM SIZE =      9266
  *STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
FORTRAN IV G1  RELEASE 2.0              MATOUT              DATE = 76320              21/26/16
                         SUBROUTINE MATOLT(A,M,N,TITLE,NR,MC)
                         REAL*8 A
                         DIMENSION A(NR,NC),TITLE(6)
                       1 FORMAT('0'/'0',6A4)
                       2 FORMAT(' ',7G18.8)
                         WRITE(6,1) TITLE
                         DO 3 I=1,M
                       3 WRITE(6,2) (A(I,J),J=1,N)
                         RETURN
                         DEBUG SUBCHK
                         END
```

```
FORTRAN IV G1  RELEASE 2.0                MATOUT            DATE = 76320          21/26/16

  *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
  *OPTIONS IN EFFECT*  NAME = MATOUT   , LINECNT =        60
  *STATISTICS*     SOURCE STATEMENTS =        11,PROGRAM SIZE =        700
  *STATISTICS*  NO DIAGNOSTICS GENERATED

  *STATISTICS*  NO DIAGNOSTICS THIS STEP
```

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